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

ANTARCTIC RESEARCH CENTRE

Annual Review 2018

CAPITAL THINKING. GLOBALLY MINDED.
MAI I TE IHO KI TE PAE

125,000 years ago

parts of the East Antarctic Ice Sheet melted contributing to 6-9 metre higher sea levels than today, according to a *Nature* paper co-authored by Rob McKay.

17 years

Andrew Mackintosh has worked for Victoria University, as he says goodbye as ARC Director.

6 *Nature* group papers

published by ARC staff; 3 in *Nature*, 2 in *Nature Communications* and 1 in *Nature Climate Change*.

2 new staff

welcomed to the ARC family, Stefan Jendersie and Richard Levy.

$49 million

over 7 years of Government investment in a Strategic Science Investment Fund (SSIF) platform for Antarctic science, directed by Nancy Bertler.

32 publications

with ARC authorship

Beryllium10

work led by Shaun Eaves opens the door for cosmogenic nuclide applications in volcanic rocks, as well as quartz. By obtaining accurate estimates of cosmogenic nuclide production rates we can help quantify rates of past ice sheet change.

45 years

after the first drill cores were taken in the Ross Sea, Rob McKay and the team on board IODP Expedition 374, retrieved the longest-ever drill ship piston core from the Southern Ocean.

$3.7 million

GNS Science sub-contract for the MBIE-funded Past Antarctic Climates (PAC) programme has ended after eight years, with numerous research outcomes.

23 presentations

given to politicians, stakeholders, schools and community groups by ARC staff and students.

three out of 10

Rutherford Foundation New Zealand Postdoctoral Fellowships, awarded to Bella Duncan, Holly Winton, and Oliver Wigmore, will be based in the ARC.

$960K Marsden Fund

awarded to Rob McKay to improve knowledge of the magnitude of ice sheet-ocean interactions.

3 IPCC Lead Authors

Nick Golledge was selected for Chapter 9 'Ocean, cryosphere, and sea level change' in the current assessment. He joins the ranks with Andrew Mackintosh and Tim Naish.

3 theses

submitted by ARC supervised students, one PhD and two MSc.

2 degrees

of global warming is sufficient to trigger long-term melting and ongoing sea-level rise from both the Greenland and Antarctic ice sheets according to research published by Nick Golledge in *Nature Climate Change*.

51 media interviews

given by ARC staff on Antarctic and climate related issues.

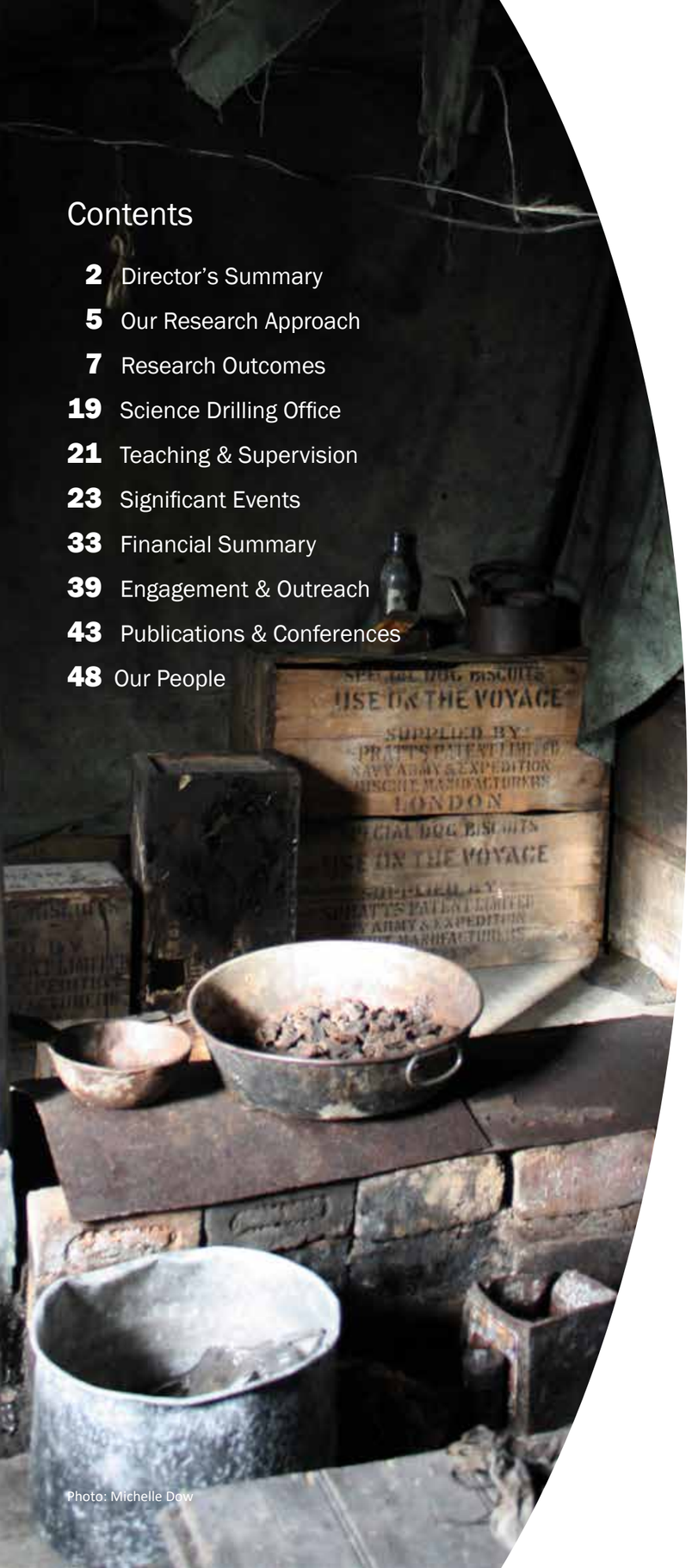


Photo: Michelle Dow

Contents

DIRECTOR'S SUMMARY

As I prepare to leave Wellington after 17 years at Victoria University, surrounded by half-packed boxes, I reflect on what we have achieved in the ARC not only in the last year but also since I arrived in Wellington in 2002. Back then, the Antarctic Research Centre (ARC) was internationally renowned for Antarctic drilling and ice sheet history, a legacy that we continue to build on today. In subsequent years and particularly during Tim Naish's reign as ARC Director, our staff and student numbers, range of expertise, and external funding portfolio expanded greatly. I was therefore lucky to be appointed as Director of a thriving, internationally renowned research centre in April, 2017.

As freshly minted ARC Director, I had a few immediate goals. It was clear that we were performing very well in terms of research outputs, and I was motivated to see whether we could do more in terms of engagement with policy makers and funding agencies. I also wanted to use my position to encourage and develop the careers of our younger researchers, including addressing the staff gender balance in our Centre. With this latter goal in mind, a major achievement in 2018 was securing three new Rutherford Postdoctoral Fellowships, with two of these awarded to female scientists. Remarkably, only ten such fellowships were awarded in New Zealand overall, which is a testament not only to the high quality of the applicants but also to the draw of our Centre. As I write, our own Bella Duncan, as well as Oliver Wigmore from the University of Colorado Boulder, USA, have just started. Holly Winton from the British Antarctic Survey, Cambridge, UK, will join us later in 2019.

We've had a terrific year of engagement, with 23 presentations to government and other influential stakeholders. Nick Golledge joined myself and Tim Naish as the third member of ARC staff to be nominated as an IPCC Lead Author, and Tim Naish participated in a panel discussion on the future of Antarctica at the POLAR18 meeting in Davos, Switzerland, hosted by *Nature* magazine. We were particularly effective at engaging with present and former New Zealand and international political leaders. In June, Rob McKay briefed the European Union Trade Commissioner Cecilia Malmström on innovations in Antarctic geological drilling and international Antarctic and geoscience collaboration at the request of Trade and Export Growth Minister Hon. David Parker. In July, I hosted a visit by former Prime Minister and head of the United Nations Development Programme, Rt. Hon. Helen Clark. And in November, Nick Golledge, Nancy Bertler and James Renwick (SGEES) hosted a visit by Minister for Climate Change, Hon. James Shaw and Luke Gaskin (MFAT).

Another key development in 2018 was the appointment of Nancy Bertler to the position of Director of the Antarctic Science Platform. This required Nancy to step aside from her own substantive ice core programme (see research outcome on the RICE project) to oversee the development of this multimillion dollar national science platform, funded by MBIE and hosted by Antarctica New Zealand. Nancy brings a ~20 year record of international scholarship and research leadership to this role, and I'm delighted for her and very proud that one of our staff was chosen to lead this critical venture. Additionally, I am pleased that Huw Horgan and Richard Levy were chosen as co-investigators of the science programme.

One area where I was looking for change in 2018 was the S.T. Lee Lecture in Antarctic Studies, where only one out of fifteen of our previous speakers had been a female scientist. All of our previous speakers have been outstanding (and I chose one of the male speakers), but this imbalance needed to be addressed. We have also had a preference for inviting very senior and distinguished scientists, whereas I thought there might also be role for inviting high-profile early to mid-career researchers. For several years, Tim Naish has been trying to persuade Valerie Masson Delmotte, co-chair of IPCC Working Group, to deliver an S.T. Lee lecture, but unfortunately her schedule has so far been too busy. So I asked our staff to nominate the most inspiring female speakers in Antarctic science right now. I received a great list of suggestions, and in 2018 invited Professor Dorthe Dahl-Jensen (Niels Bohr Institute) as the first of this group. I hope that this list provides some useful suggestions to the next ARC Director.

Another of my goals as ARC Director was to ensure that we had the correct team to lead our major projects and to answer the most pressing questions in Antarctic science. In 2018, we made two new appointments, Richard Levy from GNS Science and Stefan Jendersie from NIWA as part of the MBIE-funded NZ SeaRise programme. Stefan, appointed as a fixed-term Research Fellow, is a very talented - and I'm sure he will appreciate me saying this - young ocean modeller, who has helped to fill a significant gap; numerical modelling of ocean circulation at regional scale, including under ice shelves. This is critical expertise because most of the heat reaching the Antarctic continent leading to ice sheet mass loss is being delivered via the ocean. Future projections of the Antarctic ice sheet will remain somewhat limited in their quality until we better represent the physical processes linking the oceans to the ice. We appointed Richard Levy, a long-term ARC collaborator, Antarctic geologist and paleoclimate expert, on a permanent 0.2 FTE position to lead the NZ SeaRise programme. Richard also brings significant strategic leadership and outreach/ engagement expertise to the ARC.

Each year without fail in the ARC we publish world-class publications and bring in significant research funding. In 2018 Rob McKay led the way with a $960,000 Marsden grant which he will use to better understand the role of ocean heat in ice sheet loss over geological timescales. Rob also co-authored a *Nature* paper which demonstrated that the East Antarctic Ice Sheet lost significant mass during late Quaternary interglacial warm periods. Tim Naish and Nick Golledge also published a *Nature* paper on reconstructing the long-term history of the Antarctic ice sheet using cosmogenic isotopes preserved in legacy material from ANDRILL cores, and Tim co-authored a third *Nature* paper on the future of Antarctica, authored by recipients of the prestigious Tinker/Muse Prize for Science and Policy in Antarctica.

I start my new position as Head of the School of Earth, Atmosphere and Environment at Monash University in Australia on 1 May, and it is with mixed feelings that I prepare to move to Melbourne. I'm excited about new research and the opportunity to lead a significant academic department, particularly one with strength in both the atmospheric and earth sciences. However, I will miss working in the ARC, the School of Geography, Environment and Earth Sciences, and in Wellington with its access to government agencies and Crown Research Institutes. I will never forget the support that I received from previous ARC Directors Peter and Tim, and my rewarding collaborations with colleagues and students that became friendships - we have achieved a lot together. Michelle, I'll even miss working on this annual review together! I look forward to continuing my relationship with the ARC as an Adjunct Professor, and I wish the ARC and its new Director every success in the future.

Professor Andrew Mackintosh
Director, Antarctic Research Centre

Our mission is to improve understanding of Antarctic climate and ice sheet processes and their impact on New Zealand and the Earth system

The Antarctic Research Centre (ARC) is a centre 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, facilities and contributes to both undergraduate and graduate teaching and supervision.

Our research provides exciting opportunities and challenges for young researchers, a sound basis for international climate change assessment and will help build a more resilient New Zealand.

Photo: Dan Zwartz

OUR RESEARCH APPROACH

Rationale

We are rapidly heading towards a climate that is 2-4°C warmer than present. Ice sheets and oceans take centuries to millennia to fully adjust to climate forcing, and the fundamental changes that we are observing today may be irreversible on human timescales. In order to provide reliable, policy-relevant projections of future climate and sea level, scientists are increasingly relying on computer models. Our Centre has undergone a numerical revolution, and around half of our staff now routinely carry out physics-based computer simulations of past, present and future climate.

We develop confidence in future climate projections if models show skill at simulating present and past climate. Because direct climate and ice sheet observations span the last century at best, reconstructions of past climate conditions provide the only means to assess climate and ice sheet models on their relevant timescales. Furthermore, past climate observations provide insight into the long term “endgame” (equilibrium response), that we will commit our planet to this century based on current warming scenarios. Past climate records also provide insight into the rates and magnitudes of climate and ice sheet changes that may be possible in the near future, and allow the fingerprint of human influences to be identified in the context of natural variability in the climate system.

Outcome-based research

Our research approach is policy-relevant and outcome focused. We aim to improve forecasts of future climate change including their global and New Zealand impacts, for the benefit of humanity. By reducing the uncertainties around future climate and sea-level rise predictions, our cutting-edge research is informing the International Panel on Climate Change (IPCC). Improved understanding of climate change impacts including sea-level rise impacts in the southwest Pacific region provide tangible benefits to all New Zealanders. 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. We are funded and supported through a range of MBIE, Marsden, and Rutherford programmes, Antarctica New Zealand and private donations.

In summary, our approach involves:

a. Improving our physical understanding and observation of modern climate, ocean, glacier and ice sheet systems.

b. Acquiring past observations of surface temperature, precipitation, atmospheric composition (greenhouse gases and aerosols), ice sheet, glacier, and sea-ice variability, and oceanic conditions from terrestrial, marine, lacustrine and ice core archives.

c. Developing and improving numerical models of climate-ocean-glacier and ice sheet systems, by advancing the physics, and then carrying out sound evaluation of models against modern observations and past climate reconstructions.

d. Using our models to improve future climate simulations, and projections of glacier and ice sheet contribution to sea-level rise, river flows and other changes in the Earth System.

e. 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.

RESEARCH OUTCOMES

Photo: Cliff Atkins

CHOOSING *THEIR* FUTURE

In cities around the world, hundreds of thousands of children are protesting.

Inspired by a Swedish teenager, these children are trying - very successfully - to draw attention to climate change. But more importantly, these future voters are voicing their dissatisfaction and frustration with the current state of global climate policy. They see a future world that is very different from what it would be without greenhouse gas emissions from human activities. They want to change the path that we are currently on and choose their own future - one that keeps greenhouse warming below 2 degrees. Their figurehead, Greta Thunberg, told the audience at the recent European Economic and Social Committee in Brussels to, 'unite behind the science', a deliberate criticism of the fact that governments around the world have failed to act on what international scientific guidance has been warning since the first report of the Intergovernmental Panel on Climate Change (IPCC) in 1990.

The science we undertake in the ARC contributes significantly to IPCC reports through the journal articles we write, the international collaborations we build, and our direct representation in the authorship of these assessments. In 2018, Tim Naish, former Director of the ARC and past IPCC Lead Author, contributed to a high-profile publication in the journal *Nature* (Rintoul, *et al*., 2018) that posed the exact same question those school-children are asking today - what happens if greenhouse gas emissions remain unchecked? Looking back to the present from 2070, Tim and his colleagues used the best available science to predict what changes would have occurred in Antarctica and the Southern Ocean. Focusing on two different scenarios, the authors first imagined what Antarctica and the Southern Ocean might look like if greenhouse gases kept increasing the way they are now. In the second, they explore an alternative world in which strong mitigation took place, and the worst climate change impacts were avoided.

The findings were alarming. In the unmitigated world, rising global temperatures changed ocean currents and atmospheric circulation patterns in ways that led to greater melt of the Antarctic ice sheet, a reduction of summer sea ice, and an acceleration of global sea-level rise. Lack of proper regulation led to increased human presence in Antarctica as well as increased fishing, leading to much greater environmental degradation. Under a low emissions scenario the outlook was much better, but not completely without impacts. Sea ice only reduced slightly from present-day levels and melting of ice shelves was similarly reduced compared to the high emissions scenario. The ice sheet contribution to sea-level rise was much lower, and ecosystem impacts were much less serious.

This study drew on published research to present two alternatives for the future, essentially asking the reader to 'choose' which world we would rather live in. But it highlighted that we are already committed to ongoing changes, even with aggressive mitigation. These long-term commitments, in both the Antarctic and Greenland ice sheets, were the subject of a second high-profile paper in *Nature Climate Change* (Pattyn, *et al*., 2018), that included ARC researcher and IPCC Lead Author Nick Golledge. This paper reviewed geological and numerical modelling studies in an attempt to define the points at which ongoing loss of the two ice sheets becomes inevitable. The analysis found that both ice sheets have surprisingly low tolerances for environmental change, and that an average global warming of only two degrees is sufficient to trigger long-term melting and ongoing sea-level rise. In Greenland this arises from feedbacks with the atmosphere, whereas in Antarctica the ongoing melt is driven by ocean warming.

Both studies show that urgent and much more ambitious mitigation efforts are essential for slowing the pace at which ice sheet melt and long-term environmental change take place. In New Zealand our current government are proposing a mechanism to ensure a 'just transition' to a low-carbon economy – the Zero Carbon Bill – underpinned by a British-based economic analysis from :vivideconomics that aims to, 'help illuminate long-term low-emission pathways'. In August 2018, the New Zealand Productivity Commission published their final report to government outlining the transformations required for a 'Low-emissions economy' and stressed the urgency for 'immediate action'. So, it seems that both the science and the necessary response are clear. But the question our children pose still stands - since we know this, why aren't we doing more?

CONTACT: Nick.Golledge@vuw.ac.nz

- **Greta Thunberg's address**
  https://www.eesc.europa.eu/en/news-media/videos/speech-greta-thunberg-climate-activist

- **IPCC**
  https://www.ipcc.ch/

- **MfE Zero Carbon Bill**
  https://www.mfe.govt.nz/have-your-say-zero-carbon

- **:vivideconomics report on Net Zero in New Zealand**
  http://www.vivideconomics.com/publications/net-zero-in-new-zealand

- **NZ Productivity Commission 'Low-emissions economy' Final Report**
  https://www.productivity.govt.nz/inquiry-content/3254?stage=4

Icebergs off the East Antarctic Ice Sheet - Photo: Rob McKay

MODERATE LEVELS OF WARMING PUTS THE EAST ANTARCTIC ICE SHEET AT RISK

New *Nature* article suggests the world's largest ice sheet, the East Antarctic Ice Sheet, may have been a significant contributor to sea-level rise despite it being considered the least vulnerable.

Coral reef studies suggest that global sea levels were 6-9 metres higher than today during the Last Interglacial Period 125,000 years ago. However, global climate during this period was only 1-2°C warmer than preindustrial, and although ice sheet melt is implied for sea-level rise of this magnitude, it has long puzzled scientists which ice sheets contributed to this rise. There is evidence that Greenland remained partially glaciated at this time, and West Antarctica does not hold enough vulnerable ice to contribute to this event alone. This raises the possibility that the world's largest ice sheet, the East Antarctic Ice Sheet, was a significant contributor despite it being considered the least vulnerable to moderate levels of warming.

In 2018, a paper published in *Nature* (Wilson *et al*., 2018), and led by collaborators at Imperial College of London, found that the East Antarctic Ice Sheet was reduced in extent during this time of elevated sea level, as well as during other "moderately warmer-than-present" climates over the past 400,000 years. This suggests that some of the ice that remained on Earth after the end of the last ice age (~20,000 years ago), including that in East Antarctica, may already be primed for renewed melting.

The ARC's Rob McKay contributed to this study by identifying sediment layers related to elevated levels of iceberg discharge associated with loss of ice in East Antarctica. These layers were compared with geochemical "fingerprinting" techniques, led by David Wilson and Tina van de Flierdt (Imperial College of London). The geochemical fingerprints of the sediment were consistent with erosion of rocks that now lie far beneath the East Antarctic Ice Sheet. These combined lines of evidence showed that the ice sheet had retreated significantly inland relative to today, and was therefore a contributor to Last Interglacial sea levels.

If all of the ice that sits below sea level today were to melt, East Antarctica could contribute up to 19 metres of sea-level rise. Although these results indicate that only a fraction of this ice melted, it demonstrates that a modest but sustained warming of just 1-2 degrees is enough to cause the ice sheet in East Antarctica to retreat from some of its low-lying areas.

CONTACT: Robert.McKay@vuw.ac.nz

COSMIC SIGNALS OF PAST ICE SHEET BEHAVIOUR

Since inception of the state-of-the-art Victoria University of Wellington Cosmogenic Laboratory in 2013, ARC research driven by Andrew Mackintosh and Kevin Norton has maximised the opportunities this capability offers to interrogate past ice sheet behaviour in Antarctica.

Cosmogenic nuclides are rare isotopes (e.g. ^{10}Be, ^{26}Al, ^{3}He) produced continuously in minerals situated at Earth's surface by cosmic radiation emitted from supanovae. Accumulation of these isotopes over time can be harnessed as a useful geological clock: the longer a host rock sits at Earth's surface exposed to cosmic radiation, the greater the cosmogenic nuclide content. This technique is particularly powerful in glacial environments where flowing ice quarries rocks from depth, ultimately exposing them to cosmic radiation at ice margins. Applications in such settings offer the opportunity to directly quantify past changes in ice sheet extent over timescales of hundreds, thousands, or even millions of years.

In 2018, ARC researchers published two papers that encompass both the development and application of cosmogenic nuclide dating, which help understand past ice sheet response to climate.

In the journal *Quaternary Geochronology*, ARC Lecturer Shaun Eaves led a multi-author paper (Eaves *et al.,* 2018) that presents new estimates of the production rate of cosmogenic ^{10}Be in pyroxene. This work is significant for two main reasons. First, routine chemical techniques for ^{10}Be extraction currently only exist for quartz. Therefore this new work opens the door for cosmogenic nuclide applications in volcanic rocks, such as the Ferrar Dolerite. Second, accurate estimates of cosmogenic nuclide production rates are required to convert concentrations into exposure durations, and thus quantify rates of past ice sheet change. Building on previous ARC research at Mackay Glacier (Jones *et al*., 2015. *Nature Communications* 6 no.8910), Shaun and the team demonstrated the utility of this new technique by presenting a complementary chronology of ice surface lowering at this East Antarctic outlet glacier since the Last Glacial Maximum.

In a separate study, led by Jeremy Shakun (Boston College, USA) and co-authored by the ARC's Tim Naish and Nick Golledge, measurements of cosmogenic ^{10}Be in the Andrill-1B site revealed the long-term stability of the East Antarctic Ice Sheet. The Andrill-1B core was recovered in 2006 from beneath the Ross Ice Shelf and contains sedimentary evidence that suggests multiple periods of reduced ice sheet extent, relative to present, occurred during Earth's past warm intervals. However, outstanding questions concern the precise configuration of Antarctic ice during these past collapse events. This new work (Shakun *et al.*, 2018), published in the leading scientific journal, *Nature*, showed that quartz sand, eroded from the continent and transported to the Ross Sea by East Antarctic outlet glaciers, contains almost no cosmogenic ^{10}Be. This result is significant because it implies that the portion of the East Antarctic Ice Sheet that supplies sediment to the Andrill-1B site has remained in place, effectively shielding the continent from cosmic radiation, for the last 8 million years. Long-term stability of land-based ice, points the finger at marine-based sectors capable of rising sea level by ~22 metres during past warmer-than-present times, such as the Pliocene, 3-5 million years ago.

With in-house laboratory capability and a long tradition of successful sediment recovery from terrestrial and marine archives around the Antarctic margin, the ARC is well placed to harness this powerful cosmogenic toolbox to unlock further mysteries concerning past ice sheet dynamics. Future work will target the sensitive marine-based margins of both East and West Antarctica, which are thought to be most vulnerable to future ocean warming.

CONTACT: Shaun.Eaves@vuw.ac.nz

Beacon sandstone, Antarctica - Photo: Richard Jones

PhD student Katelyn Johnson with NZ Ice Core Facility Manager, Rebecca Pyne - Photo: VUW

EAST AND WEST ANTARCTICA AT LOGGERHEADS

The Roosevelt Island Climate Evolution (RICE) project, a NZ-led, nine-nation collaboration achieved some exciting and significant milestones.

Two age models for the past 2,700 years and 83,000 years were finalised and spliced. The 2,700 year age scale, developed under the lead of Mai Winstrup (then University of Copenhagen), takes advantage of seasonally resolved geochemical records and applies an independent uncertainty assessment using volcanic eruptions identified via geochemical peaks and one visible ash. The 83,000 year age scale, developed under the lead of James Lee (then Oregon State University), takes advantage of the high resolution RICE methane data to correlate with the West Antarctic Ice Sheet Divide (WDC) and the Greenland (NGRIP) ice core records.

The availability of these two age scales enabled the RICE team to shift their focus on the interpretation of the environmental and glaciological information contained in the core leading to the publication of a RICE community paper in *Climate of the Past* (Bertler, *et al*., 2018) with a focus on the past 2,700 years. The comparison of ice core proxies with climate data showed that the RICE records are highly sensitive to air temperature, changes in sea ice cover, sea surface temperature, atmospheric circulation pattern and marine primary productivity, providing a sensitive tool for environmental reconstructions in this important region. The high resolution age scale permitted the calculation of snow accumulation, one of only three such records from Antarctica extending past the last millennium. The RICE records show that snow accumulation continued to increase until the 15th Century, when it sharply started to decrease until modern times. This is curious as over the same time period, local temperature steadily increased, usually conducive to an increase in moisture and thus snow fall. This suggests a sensitive feedback mechanism induced by large scale changes in sea ice cover. Moreover, the RICE records show that the eastern Ross Sea and West Antarctica experienced opposing trends in temperature and snow accumulation over the past 2,700 years. During the Little Ice Age period, West Antarctica and the western Ross Sea (adjacent East Antarctica) experienced significant cooling, while the central Ross Sea (in the vicinity of Roosevelt Island), continued to warm. With an emerging network of high resolution, well dated ice core records, such regional patterns can now be detected and deciphered providing important constraints for ice sheet models projecting future scenarios.

While the RICE team is now focusing on the deglaciation, three ARC PhD students, Katelyn Johnson, Lukas Eling and Abhijith Ulayottil Venugopal have extended the geochemical records to encompass the early Holocene and glacial periods. The emerging records promise to reveal many more surprises and to improve our understanding of the inner workings of the Ross Ice Shelf, and its future behaviour, helping to quantify future sea level contributions from Antarctica.

CONTACT: Nancy.Bertler@vuw.ac.nz

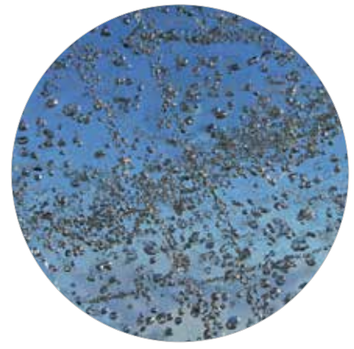
FROM BUBBLES TO GLOBAL TEMPERATURES

Ice cores record significant and abrupt past climate changes associated with large and rapid changes in atmospheric greenhouse gases, such as methane.

While our current estimates of past climates have vastly improved with ice core data, large uncertainties remain in our understanding of the relationships between greenhouse gases extracted from the bubbles and local temperatures extracted from the surrounding ice. We have developed a new method to obtain a more accurate gas signal that is less attenuated and increases the time resolution of the gas measurements in ice cores. Our first results show combined measurements/experiments from the RICE core and modelling to produce gas-trapping functions, and gain information about how many bubbles were closed off at each considered depth.

The research was presented at the SCAR/IASC Polar2018 Conference in Davos, Switzerland, and submitted to the *Journal of Geophysical Research.*

CONTACT: Ruzica.Dadic@vuw.ac.nz



DRILLING MISSION CAPTURES A 20 MILLION YEAR RECORD OF OCEAN-ICE SHEET INTERACTIONS

In 2018, an international research team travelled to the Ross Sea aboard the *JOIDES Resolution*, as part of the International Ocean Discovery Program (IODP) Expedition 374.

The expedition was led by the ARC's Rob McKay and Laura De Santis (Istituto Nazionale di Oceanografia e di Geofisica Sperimentale, Italy) and obtained five sediment cores up to 700 metres in length. The sites formed a continental shelf to deep sea transect designed to understand past oceanic-ice sheet interactions. The project was designed to build on the results of the ANDRILL project, drilled over a decade ago that provided the first clear evidence that the West Antarctic Ice Sheet (WAIS) had collapsed numerous times over the past 20 million years. The loss of this "marine based" ice sheet is thought to be due to oceanic warming melting the ice at its marine margin, rather than "top down" melting by the atmosphere.

While IODP Expedition 374 also sought to identify additional periods of major ice sheet loss, its primary goal was to identify what changes in the oceans caused the WAIS to melt. Key questions the scientists hope to answer are: how warm did the oceans directly offshore of Antarctica get before loss of the marine-based ice sheets occurred; and did shifting oceanic currents push warm waters, that currently exist further north in the Southern Ocean, closer to the Antarctic ice sheets leading to their retreat. It also anticipated the cores will answer fundamental questions about how, and when, the marine-based WAIS first formed, as well as determining what the climatic threshold was for the loss of the last land-based plants in Antarctica.

Investigation of the chemistry and fossil content in the cores, along side modelling experiments, will also help understand the implications of large freshwater releases from the Antarctic ice sheet into the Southern Ocean. The most obvious impact is sea level, but a fresher ocean could lead to changes in sea ice extent, nutrient delivery to marine plankton, and affect the way oceanic heat is transported from Antarctica to the rest of the planet - as a large component of ocean circulation near the edge of the Antarctic Continent is driven by changes in the density of surface ocean waters.

The expedition broke several long-standing Antarctic drilling records: it achieved the highest-ever recovery rate (63%) and deepest drill hole (702 m) from a drill ship core on the Antarctic continental shelf, and retrieved the longest-ever piston core (271 m) in the Southern Ocean, giving the research team one of the most pristine geological records ever obtained of ice sheet variability and oceanographic change offshore of Antarctic.

New Zealand joined IODP in 2008 through the Australia and New Zealand IODP Consortium (ANZIC). ANZIC is funded by the Australian Research Council and other research organisations and universities in Australia and New Zealand; including GNS Science, NIWA, Victoria University of Wellington, the University of Otago and the University of Auckland. The scientific drilling ship *JOIDES Resolution* is funded by the US National Science Foundation.

CONTACT: Robert.McKay@vuw.ac.nz

Laura De Santis and Rob McKay on board the *Joides Resolution* - Photo: Rob McKay

ICE SHEETS AND SEA LEVEL IN THE PLIOCENE

Why ice sheets grow and decay and their role in setting global sea level lies at the heart of our research interests.

In 2018, we started to see the culmination of several year's work on a section of Pliocene rocks deposited 3 million years ago in Whanganui Basin supported by Tim Naish's Marsden grant and undertaken by Georgia Grant as her PhD topic and presented at AGU in December. In 2018, Georgia led a paper in *Quaternary Science Reviews* outlining the detailed stratigraphy of two drill holes in the Turakina River valley that also incorporates unpublished work from two other former ARC students – Juliet Sefton and Molly Patterson.

These shallow marine sediments contain systematic changes in species of microscopic shells and grain size that point to rising and falling sea level between 2 and 3.3 million years ago. The Pliocene is a period of time when Earth's climate was warmer than present and Northern Hemisphere ice sheets were small or non-existent. For that reason, the frequency and magnitude of sea level in that period is a guide to the behaviour of Antarctic's ice sheets in a warmer world. More specifically, the evidence suggests the part of Antarctica that is thought to be relatively stable today (the East Antarctic Ice Sheet) was actively expanding and contracting in the Pliocene. The frequency of these changes is also important because they tell us something about what is driving this instability. Some theories suggest direct melting (and freezing) of ice in response to changing incoming solar radiation (insolation; as described by Milankovitch theory), whilst others highlight the importance of warmer oceans nibbling away at marine terminating glaciers and ice shelves (or some combination thereof). We hope our conclusions on these topics will be published soon!

CONTACT: Gavin.Dunbar@vuw.ac.nz

Friis Hiils, Antarctica - Photo: Tim Naish

PAST ANTARCTIC CLIMATES PROGRAMME LEGACY

Since 2010, one of the ARC's underpinning research projects has been the MBIE-funded Past Antarctic Climates (PAC) programme.

The MBIE contract, held by GNS Science (and led by Richard Levy), had a significant sub-contract to the ARC worth $3.7 million over eight years. In September 2018, this sub-contract came to an end as MBIE established the new Antarctic Science Platform.

The approach of the PAC Programme has been to integrate geological data with numerical models grounded in a robust understanding of modern processes in order to reconstruct how Antarctica's ice sheets responded during past "warmer-than-present" times, in order to provide insights into future changes and their global consequences.

The ARC team of researchers who worked on the programme include Tim Naish, Peter Barrett, Lionel Carter, Gavin Dunbar, Nick Golledge, and Andrew Mackintosh. The team were also supported by Alex Pyne and Darcy Mandeno from the ARC's Science Drilling Office. Within the ARC, PAC fully/partially funded three PhD students (Hannah Chorley, Jamey Stutz, and Ross Whitmore), and one MSc student (Libby Galbraith). Some achievements of these early career researchers include Jamey organising and chairing two workshops; one held at the Past Antarctic Ice Sheets Conference in 2017 and the other at the SCAR/IASC Polar2018 Conference, in 2018.

Examples of the achievements of the programme include future projections on what Antarctica may look like under various warming scenarios, improved understanding of the causes and consequences of 21st century ice sheet melt, and improved understanding of ice sheet loss from the East Antarctic Ice Sheet during past warm intervals. Research conducted under the PAC programme and its predecessor ANDRILL, are being integrated into guidance documents including the recently published NZ Ministry for the Environment – Coastal Hazards Strategy and the Intergovernmental Panel on Climate Change 6th assessment report. Knowledge of Ross Sea geology and glacial history generated through the PAC programme were used to guide the science objectives of other programmes such as the recently completed IODP Expedition 374 co-led by Rob McKay. Furthermore, knowledge gained regarding past, present, and future ice sheet response to climate change will inform new work being conducted under the MBIE-funded NZ SeaRise programme.

Over the eight years, numerous papers have been published in leading journals such as *Nature*, *Nature Communications*, *Nature Geoscience*, *Geophysical Research Letters*, and *Earth and Planetary Science Letters*. Results from PAC research on ice sheet response to past intervals of higher than present atmospheric CO_2 concentrations were also included in an article published in the annual World Meteorological Organisation Greenhouse Gas Bulletin. The bulletin received exceptionally high coverage in major news outlets and in many languages. So, although this programme comes to end for the ARC its research legacy will continue to shape future research on the Antarctic.

CONTACT: Tim.Naish@vuw.ac.nz

LAUNCH OF THE ANTARCTIC SCIENCE PLATFORM

2018 saw the launch of the Antarctic Science Platform, a Strategic Science Investment Fund programme providing dedicated funding from MBIE.

This exciting platform promises a new age of New Zealand led scientific exploration in the Antarctic. The broad goal of the platform is to *conduct excellent science to understand Antarctica's impact on the Earth system and how this might change in a warming world*. To accomplish this the platform has established two central work programmes: (1) The Antarctic ice-ocean-atmosphere system in a warming world, and (2) The Ross Sea region ecosystem dynamics in a warming world. Each of these programmes consists of two main projects, which broadly cover the most important aspects of the cryosphere as identified by a series of workshops and consultation. Project 1 addresses Antarctic Ice Dynamics: Past, Present, and Future and includes an ambitious work plan of direct access beneath the West Antarctic Ice Sheet. This will result in much-needed observations of the controls on ice flow, and the retrieval of stratigraphic records of past ice-sheet extent and environmental conditions.

Antarctica New Zealand has been contracted to host and implement the platform. The ARC is involved at multiple levels, with Nancy Bertler seconded to the platform directorship, Nick Golledge leading a platform-wide Future Projections advisory panel, Tim Naish leading the Previous Climate Experiments objective of Project 1, and Huw Horgan Co-Investigator alongside Richard Levy (PI) leading Project 1. Platform funding for Project 1 begins 1 April 2019, with the first field campaign of direct access at the grounding zone of Kamb Ice Stream in the 2019/2020 season. We all look forward to the bounty of science that this platform will enable.

For more information visit: http://www.antarcticanz.govt.nz/science/antarctic-science-platform/

Cliff Atkins and Gavin Dunbar, Antarctica
Photo: Dan Zwartz

A BUSY YEAR FOR THE ORGANIC GEOCHEMISTRY LABORATORY

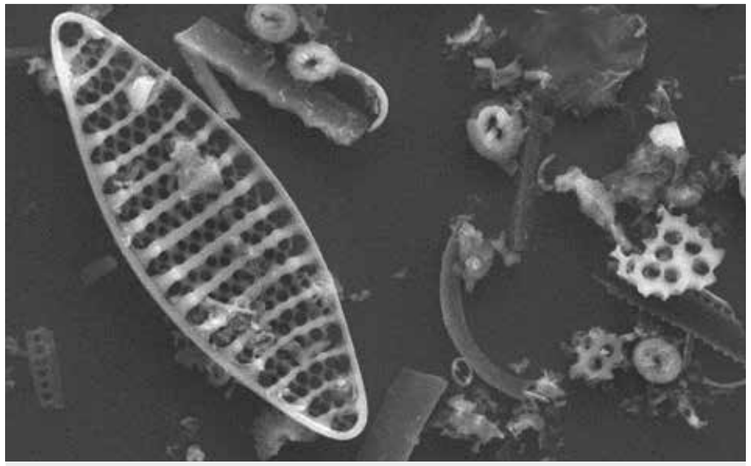
Postdoctoral Fellow Bella Duncan, together with Sebastian Naeher at GNS Science, have been developing the GNS/VUW Organic Geochemistry Laboratory.

This facility enables us to extract molecular fossils known as biomarkers from samples and identify and quantify the different compounds present to investigate what they can tell us about past climates. Now that this facility is up and running it's been a busy year in the laboratory.

Over 2018 we've had two ARC Masters students, Rebecca Pretty and Nikita Turton, and four summer research students utilise the laboratory to investigate projects as diverse as the initiation of the Great Barrier Reef, climate offshore Antarctica in the Miocene and Pliocene, and New Zealand paleoenvironment over the last 14,000 years. Among the compounds investigated are alkenones, which are used to reconstruct past sea surface temperatures, and plant waxes such as n-alkanes and fatty acids, which tell us about past vegetation, hydroclimate and carbon cycle changes.

In 2018, Bella received a Rutherford Foundation Postdoctoral Fellowship (see page 25). This fellowship will enable her to continue developing and utilising the GNS/VUW Organic Geochemistry Laboratory, as well as helping students to learn and apply biomarker techniques.

CONTACT: Bella.Duncan@vuw.ac.nz



Electron microscope view of a diatom

SOUTHERN OCEAN SEDIMENTS

Increases in carbon dioxide 'venting' from the Southern Ocean.

In 2018, MSc student Melanie Liston (co-supervised by Gavin Dunbar and Helen Bostock, NIWA) completed her study of two sediment cores from the Antarctic Polar Front (APF) region ~60^{0}S. Melanie found there are a systematic series of plankton productivity changes that recur during glacial terminations. Biological productivity of biogenic silica (overwhelmingly diatoms) in particular is linked to upwelling of nutrients from deep in the Southern Ocean's interior. Along with nutrient elements (including silicon) comes carbon dioxide (CO_2) in various dissolved forms that has accumulated from decaying organic matter. So high is the abundance of CO_2 in the Southern Ocean's depths that when these waters are brought to the surface, they 'vent' CO_2 into the atmosphere, enhancing global warming and helping drive the termination of the last ice age. Melanie found a strong relationship between biogenic silica production and the rate of increase in atmospheric CO_2 during the past two glacial terminations south of the APF. This suggests the venting of CO_2 out of the Southern Ocean was not a 'one off' process at the end of the last ice age but part of an ongoing series of events that recurs with each Pleistocene glacial termination.

CONTACT: Gavin.Dunbar@vuw.ac.nz

APPLYING RESEARCH TO INFORM A CHANGING WORLD

The ARC provides advice on the environmental impact of fibre-optic cables.

Currently, the United Nations is walking a tightrope between the use and conservation of the marine environment as exists in international waters beyond the legal boundaries of the Exclusive Economic Zone and Legal Continental Shelf. This zone, formally termed the Area Beyond National Jurisdiction (ABNJ), occupies ~65% of the ocean. It is now coming under increasing pressure as human activities, such as seabed mining, expand from shore. In that context, the ARC provides advice to the submarine cable industry. This group supplies the fibre-optic cables that underpin ~95% of global Internet traffic.

Our advice provides a scientific basis to guide discussions regarding the environmental impact of laying and maintaining fibre-optic cables in the ABNJ and elsewhere. Most recently a paper in *Ocean Engineering* by Christoph Kraus and Lionel Carter (2018) showed that disturbance caused by burying fibre-optic cables beneath the seabed – a method to protect cables from benthic fishing – was temporary. Rates of physical and biological recovery ranged from days to decades, tending to take longer in deep water where current action is limited. A companion study assessing the chemical and physical durability of cables, revealed them to be highly resilient. Most showed little degradation even though they had resided on the seabed for up to 45 years. That study will be published in 2019.

Next, is the effect of ocean/climate change on the fibre-optic network. This takes advantage of the ARC's expertise with respect to sea-level rise, storminess and sediment density flows.

CONTACT: Lionel.Carter@vuw.ac.nz

Brian Anderson undertaking a snowline survey - Photo: Dave Allen (NIWA)

GLACIER SNOWLINE SURVEYS: A NEW APPROACH AND THE END OF AN ERA

Since 2015, the ARC has taken part in the annual 'end of summer snowline survey'. This project was initiated by Trevor Chinn way back in 1978, and has been run by NIWA since the 1990s.

ARC's role, working with Drew Lorrey (NIWA), has been two-fold: to upgrade the information collected during the flights; and to re-process images taken since 1978 to extract more and higher quality data from the existing historic archive.

Brewster Glacier, which the ARC has been measuring since 2004 with colleagues from University of Otago, was the first target of this work. PhD student, Lauren Vargo, used new photogrammetry techniques and published a reanalysis of the snowline and terminus position record of this glacier in 2017.

The record-setting heat of the 2017/2018 summer, associated with a marine heat wave in the Tasman Sea, resulted in the highest snowlines ever recorded. More than half of the measured glaciers had no snow cover left at all. This is a crisis point for a glacier, because glaciers are replenished solely by winter snow that survives the summer melt.

The marine heat wave, hot summer, and subsequent record high snowlines received a lot of media attention in 2018. Behind the scenes Lauren and her colleagues are extending the snowline photo analysis and working to answer the question - could this particular year's record loss of glacier ice have happened without anthropogenic climate change?

The 2017/2018 summer may have been a step change in the loss of New Zealand's glacier ice, but there is no doubt about the heavy loss to the snow and ice research community with the death of Trevor Chinn in December 2018. Trevor's persistence in the face of adverse weather, retreating glaciers, and obstructive bureaucrats has left an incredible legacy of facts, figures, and photos of New Zealand's glaciers that simply would not exist without his inquisitive and unique brand of glaciology.

As an example, the original glacier inventory, started in 1978, was almost lost when Trevor's boss in the 1980s informed him one Friday that he was going to 'delete the tapes on Monday' even though, after years of work, the inventory of 3144 glaciers was essentially complete. Trevor paid one of his colleagues to work all weekend to print out the inventory. Sure enough the tapes were deleted and the inventory only lives on through that epic printing session.

Trevor's approach has rubbed off on many of the next generation of glaciologists, ensuring that his legacy will live on. As Trevor said in one of his last interviews "glaciers don't lie". And while this is true, he loved that glaciers could also confound common sense, as Franz Josef Glacier/Kā Roimata o Hine Hukatere did in 2017/2018 by advancing during the hottest summer on record.

https://niwa.co.nz/videos/glaciers-dont-lie

CONTACT: Brian.Anderson@vuw.ac.nz

EXTENDING HISTORIC GLACIER LENGTH RECORDS USING COSMOGENIC EXPOSURE DATING

Retreating mountain glaciers are prominent icons of present-day climate change, due to their acute sensitivity to changes in air temperature.

Glacier forelands often contain rich geological evidence of former ice extents, in the form of landforms such as moraines, which document how glaciers have varied in size over the past few centuries to millennia. These archives offer the potential to extend our understanding of how glaciers, and thus climate, have changed over timescales that exceed instrumental climate measurements. However, achieving precise dates for these young glacial landforms has, until recently, proved difficult.

In recent work funded by the National Geographic/Waitt Program, we have applied cosmogenic ^{10}Be surface exposure dating to produce precise dates for pre-historic moraines at Dart Glacier in the Southern Alps. This technique utilises concentrations of the rare isotope, ^{10}Be, which builds up in glacial sediments over time due to interaction with cosmic radiation. To date landforms deposited by Dart Glacier just a few centuries ago, we collaborated with Lawrence Livermore National Laboratory in the USA, who have the capability in accelerator mass spectrometry to resolve such small ^{10}Be concentrations. Our results show a prominent advance of Dart Glacier that culminated at the end of the 17th century. This new data extends the relatively rich observational record of Dart Glacier, which was first mapped in 1915, and provides a useful target for future numerical modelling experiments in which we seek to determine the geological precedence of recent glacier retreat in the Southern Alps.

CONTACT: Shaun.Eaves@vuw.ac.nz

Sea wall protecting the town of Granity, West Coast from sea-level rise - Photo: Tim Naish

NZ SEARISE PROGRAMME ON THE RISE!

The New Zealand SeaRise programme, aims to produce improved location specific predictions of sea-level rise to 2100 and beyond.

Richard Levy took over leadership of the programme, from Tim Naish, when he was appointed Associate Professor (0.2 FTE) at the ARC in November 2018. Tim remains in a leadership role joining Rob Bell (NIWA) and Nick Golledge as project leaders. We have made significant progress towards reducing global and local uncertainties that affect our ability to predict sea-level rise. Namely, by improving estimates of polar ice sheet melt and accounting the significant influence of vertical land movements around the New Zealand coastline. The latest estimates of polar ice sheet and glacier melt, ocean thermal expansion, land water storage, vertical land movements, ocean dynamics are being combined within a probabilistic framework using international best-practice methodology of our USA collaborator, Bob Kopp (Rutgers University). We hope to have a preliminary set of projections for NZ tide gauges for a range of future climate scenarios by the end of 2019. As the science is evolving, we are developing case studies with local authority partners (Otago Regional Council, Greater Wellington Regional Council, Hawke Bay Regional Council) and Iwi (Ngati Kahugnunu), to understand the impact of the sea-level projections on coastal flooding and storm surge recurrence, groundwater salination and inundation, and coastal estuarine environments. Ultimately our projections will strengthen national policy statements and hazards planning guidance documents (e.g. MfE, LGNZ, DOC), and scientifically robust local projections will strengthen the statutory mandate for adaptation decision-making.

CONTACT: Richard.Levy@vuw.ac.nz

LAKE OHAU LAYERING

Sediment layering reveals frequency of environmental events such as earthquakes, flooding and beech 'masting'.

The ARC's Gavin Dunbar and collegues continue to advance work on the detailed stratigraphy of the Lake Ohau cores with recent publications in *Scientific Drilling* and *Quaternary Science Reviews* (Levy, *et al.*, 2018 and Vandergoes, *et al.*, 2018). Much effort has gone into a quantitive method to count the annual layers evident in the core x-rays (with assistance from Euan Smith, SGEES) and we now have a layer-counted stratigraphy for our lower sedimentation site that extends back ~5000 years. The record is interrupted by a disturbed interval dated to 3300 years before present that appears to correlate with the last known movement on the Ostler Fault that passes south of the lake.

Layer counting is important not only for dating the core, but also for examining the stratigraphy in great detail. For example, Joe Prebble and Xun Li (GNS Science) have shown we can identify 'mast' years (years of greatly enhanced seed production) from the abundance of pollen extracted from the sediment. Abundant food from Beech forest masting in particular leads to a huge growth in predator populations that turn on native fauna as the supply of seeds run out if they are not actively managed. The long pollen timeseries available from Ohau sediments includes periods of the past both warmer and cooler than today and examining the frequency and magnitude of masting events in the past will help us gain a better understanding of the climatic cues that help trigger them. We also know that major flood events deposit anomalously thick layers of fine sediment – up to three times the annual average and layer counting enables us to identify these years. Long term trends (if any) in the frequency of these beech masting events and major floods is the current focus of our research, now the ground work has been done.

CONTACT: Gavin.Dunbar@vuw.ac.nz

Unconformity possibily caused by earthquake shaking ~3300 years ago

SCIENCE DRILLING OFFICE

The Science Drilling Office (SDO) is currently preparing for future programmes on the ice.

The SDO is hosted in the ARC and led by Alex Pyne SDO Director and ARC Projects Manager, along with Darcy Mandeno as Operations and Field Engineer. SDO activities in 2018 have not included a 2018-19 field season in Antarctica, which has been a welcome break, and has allowed the team to start addressing housekeeping issues that are becoming increasingly problematic as we continue to support equipment and logistics-heavy field activities in Antarctica.

Over the 2017/2018 summer our small warehouse and workshop facility at the Karori Campus was moved to new leased premises in Lower Hutt. The relatively small space (133 m^2) required several weeks of reorganisation but is now a compact and functional facility designed to enable us to better service and repair equipment in New Zealand primarily in preparation for annual Antarctic field activities. Our operational model still requires larger equipment to be purchased and constructed out-of-house under our leadership in design and innovation.

Darcy is developing a practical field-friendly way to inventory and track our increasingly complex range of field equipment that at any time may be wintered in a remote locations in Antarctica, stored at Scott Base, in transit, or being stored and serviced at the workshop.

A major aspect of our continuing Hot Water Drilling programme has been the unsatisfactory performance of the diesel generators that support this operation. In 2018, the SDO temporarily contracted Jeff Rawson, who has previously worked with us for several Antarctic field seasons, to review options for field generator replacement in 2019. The issue is cold temperature operations and use of aviation kerosene replacing diesel fuel. Jeff found replacement engine options, we secured CAPEX for 2019, and will be repowering the generators with larger lower technology Duetz engines better rated for kerosene based fuels.

In the second half of the year Alex started working on the concept for a new “light weight” drilling capability to access marine geological sea floor record beneath ice shelves. The concept for this drilling capability is to complement and integrate with our successful Hot Water Drilling operations and be initially deployed as part of the Ross Ice Shelf project and Antarctic Platform programme. We anticipate that the CAPEX funding, design, procurement and manufacture to be carried out in 2019 -2021 for first drilling in the 2021-22 Antarctic season.

CONTACT: Alex.Pyne@vuw.ac.nz

Photo: www.neilsilverwood.com

TEACHING & SUPERVISION

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

The ARC supports a significant proportion of the research being carried out in the paleoclimatology theme through teaching and graduate supervision. There is also a close interaction between ARC staff and projects with other research programmes in geophysics, geology, physical geography, and the environmental studies programme. Our teaching contribution includes lectures in both undergraduate and graduate courses as well as supervision of graduate students enrolled with the School of Geography, Environment and Earth Sciences (SGEES). In 2018, our staff supervised 16 PhD and 7 MSc students and contributed to the following courses:

COURSES WE TAUGHT IN

ESCI 111	The Earth System: An Introduction
ESCI 132	Antarctica: Unfreezing the Continent
ESCI 201	Climate Change and New Zealand's Future
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 321	Ice and Climate
GEOG 325	Field Methods
ESCI 403*	Stratigraphy and Palaeoenvironments
ESCI 404*	Topics in Earth Sciences
ESCI 412*	Paleoclimatology
PHYG 414	Climate Change: Lessons from the Past
ESCI 580	Research Preparation

* An ARC staff member was the course co-ordinator

GRADUATE COMPLETIONS

Georgia Grant (PhD)
"Pliocene glacial-interglacial sea-level change."
Supervised by Tim Naish and Gavin Dunbar (ARC).

Melanie Liston (MSc)
"Glacial-interglacial productivity in the Polar Frontal Zone, southwest Pacific Ocean."
Supervised by Helen Bostock (NIWA) and Gavin Dunbar (ARC).

Karsten Lorentz (MSc)
"Bedrock to soil: In-situ measurement and analytical techniques for initial weathering of proglacial environments."
Supervised by Kevin Norton (SGEES) and Brian Anderson (ARC).

Photo: Peter Barrett

Image: Roald Amundesen, Fram Museum

SIGNIFICANT EVENTS

Victoria's IPCC authors: Dave Frame, Andrew Mackintosh, Judy Lawrence, Nick Golledge, and James Renwick
Photo: VUW Image Services

ARC EXPERTISE A MAJOR CONTRIBUTOR TO IPCC ASSESSMENT

Two ARC researchers have now been confirmed as Lead Authors in the sixth assessment cycle (AR6) of the Intergovernmental Panel on Climate Change (IPCC) - the world's leading independent assessment of our changing climate.

Andrew Mackintosh and Nick Golledge are joined by three other Victoria University academics; Dave Frame and Judy Lawrence (Climate Change Research Institute), and James Renwick (School of Geography, Environment and Earth Sciences). Together, they make up one of the larger groups of Lead Authors from any organisation to be involved in preparing the report.

"It's rare to have five Lead Authors from one institution selected for the same assessment cycle," said Andrew. "Victoria University is very strong in climate science across a wide range of areas relevant to society - including climate physics, global and regional climate change, ice sheets and sea-level rise, and adaptation - which gives us a significant advantage when working on these reports."

The IPCC produces a range of reports that assess scientific, technological and socio-economic information from different areas over the last five years. The reports look at the science of climate change, the impacts of climate change, and mitigation of climate change across the globe.

Nick will be our third ARC Lead Author, joining Tim Naish, who was a Lead Author in the fifth assessment report (AR5), and Andrew, who is a Lead Author in the Special Report on the Oceans and Cryosphere in a Changing Climate (SROCC), which also forms part of AR6. Nick will work in Chapter 9 'Ocean, cryosphere, and sea level change' of the main assessment report. Andrew said,

"Nick's expertise in ice sheet modelling and projected changes in the Antarctic ice sheet will be critical for considering how sea level will rise in the 21st Century and beyond. This is one of the key areas where things have changed since the publication of AR5 in 2013."

Nick's role in this chapter is also closely aligned with the MBIE funded NZ SeaRise Programme led by Richard Levy, providing a boost to the international connections and stakeholder engagement aspects of this major ARC project.

Andrew is continuing his work as a Lead Author of Chapter 3 'Polar Regions' of SROCC. He is assessing how climate change is influencing polar ice sheets and glaciers, and how these changes are affecting oceans, ecosystems and people. Andrew's role is closely aligned with the anticipated focus of the Antarctic Science Platform recently supported by the MBIE Strategic Science Investment Fund.

The contribution to be made by Victoria University staff is significant says Nick.

"Our involvement in this report really demonstrates the strength of our international research and recognises the significant scientific contributions we are making."

ANTARCTIC RESEARCH BENEFITS FROM THREE RUTHERFORD POSTDOCTORAL FELLOWSHIPS

Congratulations to Bella Duncan, Holly Winton and Oliver Wigmore who are among ten researchers nationwide awarded Rutherford Foundation New Zealand Postdoctoral Fellowships.

All three will be based here in the ARC. The two-year fellowships from the Royal Society Te Apārangi are for promising researchers in the early stages of their careers. Four fellowships were awarded to Victoria University.

ARC Director, Andrew Mackintosh says the Centre is delighted to secure three Rutherford postdoctoral fellowships.

"This provides further evidence of our standing as a leading global research centre, attracting the brightest young international scholars to Wellington, and also supporting our home grown talent."

Bella Duncan, who completed her PhD in 2017 with the ARC's Rob McKay and Tim Naish, has been awarded her fellowship for research into the role that atmospheric warming has played in driving ice sheet retreat and Antarctic environmental change in the past. She will use molecular fossils to reconstruct past Antarctic climate, air temperature, and vegetation.

Holly Winton will conduct research using biomarker techniques on Antarctic ice cores to study marine primary production—tiny photosynthetic plants that float in the upper ocean—in the Ross Sea over the past 2000 years. The research aims to answer how primary production changed over this time period and what drove the change.

Bella was already working in the ARC, and Holly, who completed a Master's degree with the ARC in 2011, has been working for the British Antarctic Survey in Cambridge in the United Kingdom since completing her PhD.

Oliver Wigmore, from the University of Colorado, Boulder, will map changes in the debris-covered tongue of New Zealand's biggest glacier—the Tasman—using drones, satellites and field observations. The data will improve our understanding of how debris-covered glaciers respond to climate change.

The ARC team is very pleased to continue working with Bella and welcome Holly and Oliver in 2019.

ARC's new Rutherford postdoctoral fellows, Bella Duncan, Holly Winton, and Oliver Wigmore

AWARDS AND APPOINTMENTS

In 2018 ARC staff and students were awarded the following:

Awards

Bella Duncan — Rutherford Postdoctoral Fellowship.

Florence Isaacs — Antarctica New Zealand Doctoral Scholarship.

Rob McKay — Marsden Fund grant on Antarctic ice sheet-ocean interactions.

Jamey Stutz — Science Media Centre 90 second video competition winner.

Lauren Vargo — Best PhD presentation at the New Zealand Snow and Ice Research Group Workshop.

Ross Whitmore — Antarctic Science International Bursary.

Oliver Wigmore — Rutherford Postdoctoral Fellowship.

Holly Winton — Rutherford Postdoctoral Fellowship.

Promotions

Nick Golledge — Promoted within the Associate Professor scale in the 2018 Academic Promotion Round.

Appointments

Nancy Bertler — Appointed as the MBIE Antarctic Science Platform Director.

Nick Golledge — Selected as IPCC Lead Author in Chapter 9 'Ocean, cryosphere and sea level change.

Huw Horgan — Co-Investigator leading the MBIE Antarctic Science Platform Project 1: Antarctic Ice Dynamics: Past, Present, and Future.

Tim Naish — Appointed to the NZ Tertiary Education Commission Physical Sciences PBRF evaluation committee.

Tim Naish — Convenor of Scientific Committee on Antarctic Research, new strategic research programme planning group for Antarctic Ice Sheets and Sea-Level Rise.

Tim Naish — Appointed as Convenor of the World Climate Research programme (WRCP) "Melting ice and Global Consequences."

Helen Clark with Lauren Vargo, Andrew Mackintosh, Brian Anderson and Heather Purdie (back to camera) - Photo: VUW Image Services

VISIT BY HELEN CLARK SPARKS DISCUSSION ON THE FUTURE OF GLACIERS

The ARC was delighted to host Rt. Hon. Helen Clark to share details of key research projects seeking to better understand the impact climate change is having in New Zealand.

In July, Helen Clark spent time with staff and students from the Centre before sitting down with ARC's Andrew Mackintosh, Brian Anderson, and PhD candidate Lauren Vargo, Sam Dean (NIWA), and Heather Purdie (University of Canterbury), who all talked about their areas of research focus.

Helen Clark said she had accepted the offer because she was seeing the incredible impact climate change is having on some of the most vulnerable communities in the world, and the increasing extreme weather and storm events.

"I've found that for the developing countries their focus was very much on adaptation. But of course we know that unless you're addressing the source of the problem you can't adapt your way out of it. In the end you have to mitigate and that involves getting the carbon footprint down."

"These are the issues that I have a passionate interest in, and catching up with the latest scientific research is extremely important, because I will keep commenting on these issues."

A particular focus was the changes observed in glaciers due to climate change, both in New Zealand and worldwide, and the trickle down effects this would have for communities who lived near them and relied on them for access to clean water and irrigation.

Andrew shared research showing that glaciers are retreating significantly throughout the world.

"Glaciers have been retreating since the early 20th Century, but ice loss has accelerated in recent decades. The problematic areas are arid areas—particularly in central Asia and South America. Communities there often rely on water that runs off melting snow and ice. By looking at climate change features and doing some simple calculations, there's estimations that this could impact at least 60 million people."

Discussions then moved on to a New Zealand context, Lauren shared insights on the NIWA End of Summer Snowline Survey, which has provided an ongoing record of key New Zealand glaciers since 1977. Every year at the end of summer ARC and NIWA scientists take to the air to take photos of 50 glaciers.

"We're taking hundreds of photos of each, and by geotagging them and using modelling software we can now generate 3D models of glaciers, which visually show the changes in glacier size over the past 40 years," said Lauren.

Brian discussed the effects this changing glacial landscape might have.

"There are more than 3,000 glaciers in New Zealand, and when they melt, they impact different parts of New Zealand in very different ways, even in quite a small geographic area—along the West Coast, an increase in meltwater can lead to flood events, while at the same time, the loss of glaciers in Canterbury will impact on irrigation and hydropower, and in Southland, the timing of the melt will impact on lowland water quality."

A tangible example that Brian gave was the changes observed on the Franz Josef Glacier which, he pointed out, had retreated 1.5 km since 2012.

"If we don't start to take action to mitigate climate change then it's a nightmare scenario for glaciers. All we'll have are some glaciers on the highest peaks—well known glaciers like Fox and Franz Josef will be almost gone. If we follow the Paris agreement and start reducing greenhouse gas emissions quickly and start taking it out of the atmosphere after 2050, then we'll have smaller but still spectacular glaciers. It's really up to us."

Helen Clark with Bella Duncan

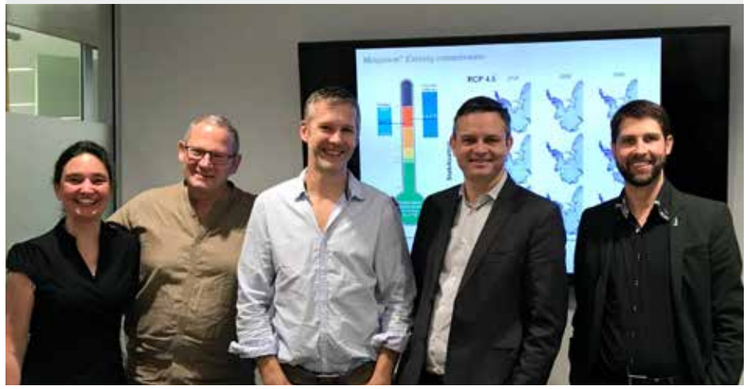
ARC CONTINUES RELATIONSHIP WITH GREEN PARTY LEADER

The ARC hosted the third in a series of meetings we have had with the Minister for Climate Change, Hon. James Shaw.

These meetings initially arose opportunistically but which have since proved to be mutually beneficial. At the meeting in November, it was both an opportunity to update the Minister on recent developments in Antarctic and climate change science, and to brief him on what to expect on his subsequent trip to the ice with Antarctica New Zealand.

During the meeting the ARC's Nick Golledge and Nancy Bertler along with James Renwick (SGEES) talked extensively about Antarctic sea ice, ocean-forced retreat of Antarctic glaciers, the difficulties in measuring and modelling these systems, and ultimately what future projections of Antarctic ice sheet change might mean for New Zealanders. The Minister was particularly interested in the long-term sea-level rise implications of our current greenhouse gas emissions trajectory, and how mitigation might be able to slow the rate of ice sheet retreat. During his subsequent trip south the Minister saw first-hand the Antarctic landscape and met with a range of scientists at Scott Base.

Nancy Bertler, James Renwick (SGEES) and Nick Golledge, speak with James Shaw and Luke Gaskin (MFAT) - Photo: Nick Golledge



PRESENTATION TO EU TRADE COMMISSIONER AND MINISTER OF TRADE AND EXPORT GROWTH

In June, Rob McKay presented to EU Trade Commissioner Cecilia Malmström and the Hon. David Parker, Minister of Trade and Export Growth, during the formal launch of NZ-EU trade negotiations in Auckland.

Rob's talk focused on the innovations associated with the unique ANDRILL drilling system, designed by the ARC's Scientific Drilling Office. He also discussed the scientific outcomes that resulted from this revolutionary project that obtained climate records from beneath the Ross Ice Shelf; and its ongoing legacy in informing models used to assess potential Antarctic ice sheet contributions to future sea-level rise. The discussions emphasized the strong ongoing scientific cooperation that exists between New Zealand and our European partners, not only with ANDRILL, but also Antarctic science and environmental stewardship in general.

DRILLING FOR PAST ANTARCTIC CLIMATE - THEN AND NOW

Christchurch event connects drilling 'Then and Now' for Past Antarctic Climate.

The *JOIDES Resolution* and its science team led by Rob McKay and Laura De Santis returned to Lyttleton in late February, 2018, after six weeks of drilling in the Ross Sea, with new discoveries on ice sheet and ocean dynamics over the last 20 million years. This was IODP Leg 374 and the first voyage to follow the GLOMAR Challenger, which visited the same port 45 years ago to change teams from DSDP Leg 28 and 29 for the first expeditions to the Ross Sea and Southern Ocean.

An event to celebrate the return of the "JR" took place on 8 March in the Lyttleton Arts Factory, with talks from leading scientists representing both scientific forays south to an audience of ~80. The first session (Then), MCed by Tim Naish, was introduced by James Kennett, key planner and co-chief scientist on Leg 29, followed by Fred Davey, on the Eltanin for the seismic surveys for Leg 28, and Peter Barrett, sedimentologist on Leg 28, with a short film of the cruise. For the second session (Now), MCed by IODP staff scientist Denise Kulhanek, Laura De Santis provided the background, and Rob McKay some of the principal results. The discussion featured similarities and contrasts between the two eras - same sense of excitement and discovery, bigger science team and better gender balance. The event has been captured in a series of videos on the SCAR-PAIS website:

https://www.scar.org/scar-news/pais-news/drilling-for-past-antarctic-climate-then-and-now/

S.T. LEE LECTURE IN ANTARCTIC STUDIES

Professor Dorthe Dahl-Jensen, an internationally respected and award-winning ice scientist at the Niels Bohr Institute, University of Copenhagen, presented the 16th annual S.T. Lee Lecture.

Dorthe Dahl-Jensen

Dorthe's lecture, "Greenland ice cores tell tales of past sea-level contributions from Antarctica", focussed on how the Greenland ice sheet is reacting to climate change—progressively losing more mass every year. One future challenge is adapting to rising sea level so by looking into how ice sheets react to changing climate in the past, we can improve future predictions of sea-level rise.

During the last interglacial, 130,000-115,000 years before present, climate was 5°C warmer over Greenland, and global sea level was 6-9 metres higher than present. All ice cores from Greenland show that the ice sheet survived, making only a modest contribution to global sea- level rise of approximately 2 metres. These findings imply that Antarctica was a major contributor to sea-level rise during this past warm period, and may respond similarly in the future.

ARC Director, Andrew Mackintosh said it is challenging to work out exactly where Antarctica's sea-level rise contribution of 4-5 metres may have come from. A sea level contribution of this size requires total loss of marine-based parts of the West Antarctic Ice Sheet, but also ice loss from coastal sections of East Antarctica.

Dorthe and Andrew agree that there are a lot of unknowns in trying to tease out what happened to the great ice sheets in the past, how they might react to different amounts of future warming and what the resulting rise in sea level might be.

"One of the biggest uncertainties is our behaviour in the future," said Dorthe.

"Because how strong the temperature change is going to be depends on how we react and how much greenhouse gases we put in the atmosphere."

Andrew Johnson on the Tongariro Crossing, New Zealand - Photo: Andrew Johnson

S.T. LEE YOUNG SCIENTIST EXCHANGE

In 2017 two recipients received the S.T. Lee exchange award. The second recipient, Andrew Johnson, arrived in New Zealand in February 2018 to work on the Parallel Ice Sheet Model.

The goal of the modelling experiment was to determine the dynamic response of Antarctic ice sheets if all of the large masses of floating glacial ice, called ice shelves, instantly collapsed. To accomplish this task Andrew initialized a model of Antarctica in Parallel Ice Sheet Model (PISM) and used a specific command which removed all floating ice at each timestep of the model run. Andrew spent two weeks in Wellington and over that time to setup and configure PISM for this scenario and produce five and ten kilometer resolution simulations for all of Antarctica with time spans of 1000 years. He tested the sensitivity of the ice response to three physical parameters relating to the dynamics of ice and the slipperiness of the ice bed. Andrew presented the results of his modelling experiments to the ARC and talked about his other research in Alaska. Andrew said,

"This travel has been greatly beneficial to me professionally. The modelling experiments I conducted at the Antarctic Research Centre should form the basis for one chapter of my PhD dissertation. The topic of this chapter will be modelling the response of ice on the Antarctic Peninsula to the collapse of ice shelves." Collaborating with Nick Golledge has greatly advanced the work on this project because of his unique expertise and resources for applying PISM to Antarctica. Nick has produced an accurate, high-resolution model of the present-day configuration of ice across Antarctica. Andrew has been able to use this model as the initialization point for his own modelling experiments. Upon returning to Alaska he will continue to work on this project by applying similar PISM runs on regional scale models of the Antarctic Peninsula with higher resolution.

"This travel has also afforded me the opportunity to broaden my horizons in the field of glaciology and to make new connections within the community. At the Antarctic Research Centre I had the opportunity to learn about the work that a number of researchers and graduate students are doing and was able to introduce my own work to them. As an early career scientist I am excited to build such connections in hopes of future collaborations throughout my career."

"I would like to say a very large thank you to Lee Seng Tee, the S.T. Lee Foundation, the Antarctic Research Centre, and the International Arctic Research Center for supporting this exchange for myself and future students."

A NEW DIRECTION FOR THE 2018 S.T. LEE EXCHANGE

The S.T. Lee Exchange has a 15-year legacy supporting students of glaciology and climatology. Leo Pure was therefore surprised when his application outcome read "you'll be the first volcanologist supported by this exchange". So what can volcanoes tell us about climate?

Since the 1950s, a small number of volcanologists have recognised that lava flows can be buttressed by ice, which often produces spectacular landforms covered with fine-scale cooling joints. Incidentally, such landforms are also paleoclimatic records of ice thicknesses. This concept has been applied with large success in the Tongariro National Park, New Zealand which is a focus of Leo's PhD research. Thanks to Dr Lee, IARC Director, Hajo Eicken and ARC Director, Andrew Mackintosh, Leo was able to share the results of my glaciovolcanic studies with scientists at the University of Alaska- Fairbanks, the Alaska Division of Geological and Geophysical Surveys (Fairbanks) and the USGS Alaska Volcano Observatory (Anchorage).

Leo's visit to Fairbanks spurred a collaboration with researcher Pavel Izbekov to examine the relative outputs of magma and gas at selected (well-monitored) circum-Pacific stratovolcanoes.

"Because many of these volcanoes have experienced glaciation, we need to understand how ice has affected the preserved volume of material on each volcanic edifice. Without considering glaciovolcanic processes, it would be impossible to accurately quantify variations in magma output through time."

Leo Pure in Denali National Park, Alaska
Photo: Leo Pure

The Amundsen Exhibition - Photo: VUW Image Services

LESSONS FROM THE ARCTIC - AMUNDSEN EXHIBITION

The Antarctic Research Centre and School of Architecture in association with the New Zealand Antarctic Society and the Norwegian Honorary Consulate General arranged the Wellington showing of the Fram Museum Exhibition "Lessons from the Arctic—How Roald Amundsen won the race to the South Pole".

In December 1911, Roald Amundsen planted the Norwegian flag at the South Pole, just weeks ahead of British polar explorer Robert Falcon Scott, who was approaching by another route. How did Amundsen succeed? The panel exhibition of images and personal accounts explained in detail how Amundsen spent his youth preparing for a life in the Polar Regions, including his three years spent learning from the Inuit in the Arctic. It gave an insight into why he used Greenland dogs, why he tore out the old steam engine in his ship, the *Fram* and replaced it with a diesel engine, and why Lindstrøm cooked American Hotcakes for breakfast every morning. The rare images displayed were taken by the expedition crew and hand-coloured by Amundsen himself.

The month long exhibition, sponsored by the Royal Norwegian Embassy, Canberra, included a ceremony on the 7 February opened by the Ambassador of Norway, Her Excellency Ms Unni Kløvstad, along with public events including the screening of the Amundsen episode from *Ten Who Dared*, a 1977 series narrated by Anthony Quinn and three public talks. Ursula Rack's (Gateway Antarctica, University of Canterbury) talk "Race to the South Pole: A historian's view" covered some of the circumstances of the race itself noting it was an event of enormous effort in an extreme environment, driven by science, politics and proving themselves in the context of their time. James Renwick's (SGEES) and Tim Naish's (ARC) combined talk "A race to save the pole: A scientist's view" explained how the Antarctic ice sheet is now changing in response to global warming, and the increasing risk that it could be too late to save the South Pole as we know it. And finally, Pip Cheshire (Cheshire Architects, Auckland) "The nature of building on the Antarctic continent: An architect's view" talked about his experience working on the conservation of iconic huts on the continent—Scott's Huts at Cape Evans and Hut Point; Shackleton's Hut at Cape Royd's; and Hillary's Hut at Pram Point on Scott Base.

POLAR 2018 CONFERENCE

ARC were well represented at the conference with 13 participants out of a 72-strong New Zealand contingent.

The XXXV SCAR Open Science Conference was a joint meeting between the Scientific Committee on Antarctic Research (SCAR) and the International Arctic Science Committee (IASC). The meeting, held in Davos, Switzerland from the 15-26 June 2018, was collectively called POLAR2018 – "Where the Poles come together". It brought together the world's leading Antarctic and Arctic researchers for the first time since the International Polar Year of 2007-2008, and also included high alpine researchers, whose research area (particularly in central Asia) is often considered as "the third pole".

ARC staff and students were well represented at the conference. Tim Naish, Peter Barrett, Nancy Bertler, Ruzica Dadic, Nick Golledge, Huw Horgan, Lukas Eling, Katelyn Johnson, Dan Lowry, Jamey Stutz, Abhijith Ulayottil Venugopal, Laurine van Haastrecht and Ross Whitmore, were part of the 72-strong New Zealand contingent. Nancy and Tim chaired workshops for the Antarctic Climate in the 21st Century (AntClim21) and Past Antarctic Ice Sheet Dynamics (PAIS) SCAR strategic research programmes (SRPs), respectively. The six SRP's (see https://www.scar.org/science/srp/) will finish in 2020. SCAR is developing a future research strategy that more directly addresses the role Antarctica plays in the rapid pace of environmental change, the risks facing humanity and the growing global sustainability problems it brings. The XXXV SCAR Delegates Meeting following the conference approved a Programme Planning Group (PPG) and budgets for 3 new programmes. Tim is leading one of these provisionally entitled Antarctic Ice Sheet Dynamics and Global Sea Level (AISSL). The aim to "quantify the Antarctic ice sheet contribution to past and future global sea-level change, from improved understanding of climate, ocean and solid Earth interactions and feedbacks with the ice, so that decision-makers can better anticipate and assess the risk in order to manage and adapt to sea-level rise and evaluate mitigation pathways".

Peter Barrett, Laura De Santis (OGS, Italy) and US educator Kimberly Kenny, hosted an evening event showcasing 50 years of scientific ocean drilling and discovery around Antarctica from the pioneering expeditions in the early 1970s to the most recent drilling leg last February in the Ross Sea led by Laura and ARC's Rob McKay. Tim also chaired a lively panel presentation and Q and A on Polar Change and the Future of Society', sponsored by the journals *Nature* and *Nature Communications* to celebrate 60 years of SCAR and the production of a special *Nature Insight* issue. Panellists included Steven Chown, host & SCAR President, Mike White, senior editor *Nature*, Steven Rintoul lead author of "Choosing the Future of Antarctica" *Nature* paper, Andy Shepherd, lead author ice sheet mass balance review in *Nature*, Dame Jane Francis, Director of the British Antarctic Survey, Jane Rumble, UK Foreign Office, and Marcelo Leppe, Director of the Chilean Antarctic Institute.

The research presented by ARC continues to be of the highest quality and attracts a lot of interest whether it be ice sheet modelling, past ice sheet reconstructions from geological and ice core data or geomorphic reconstructions using cosmogenic isotopes.

ARC CONTRIBUTES TO 60 YEARS OF SCAR AND 50 YEARS OF SCIENTIFIC OCEAN DRILLING

SCAR celebrated its 60th birthday at POLAR2018 and to mark the occasion SCAR engaged videographer Stephen Curtain to produce a video outlining its achievements.

The video includes commentary and footage from Peter Barrett's "Challenger Sails South" on DSDP Leg 28, followed by commentary from Laura De Santis and footage from IODP Leg 374. Together they outlined the contribution of Antarctic scientific drilling to science in the context of SCAR's overall coordinating role. The video link is in the "Celebrating SCAR's Rich History" section of the 2018 end-of-year message at https://scar.org/general-scar-news/greetings-from-secretariat/

Last year was also the 50th Anniversary of Scientific Ocean Drilling (DSDP/ODP/IODP), which was celebrated in the Ross Sea on IODP Leg 374. The head of the shipboard outreach team Kimberly Kenny produced an 11 minute video for IODP titled "Antarctic Scientific Deep Sea Drilling: A Long History" that includes not only a brief history of the Deep Sea Drilling Project and its successors but also the series of ARC-led Antarctic drilling projects on floating ice from DVDP15 to ANDRILL. The video featured at the American Geophysical Union's Fall Meeting, Washington DC, December 2018:

https://www.youtube.com/watch?v=GN9faSiGUZQ.

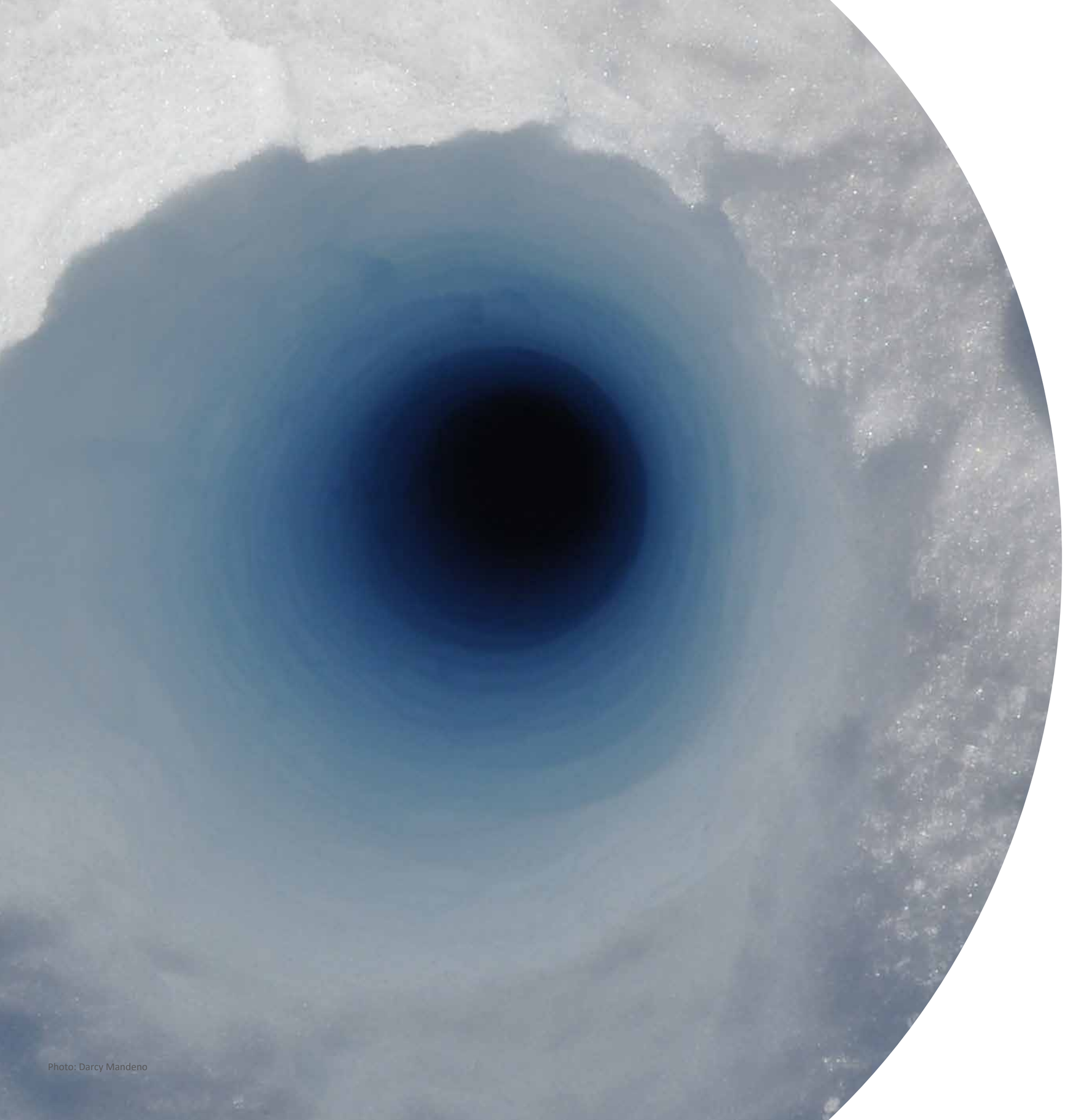


Photo: Darcy Mandeno

FINANCIAL SUMMARY

FINANCIAL SUMMARY

The ARC has continued to increase revenue with a record total of $4.37 million in 2018 thanks primarily to Ministry of Business, Innovation and Employment funded programmes.

The ARC finances include both a Centre budget and grant funds held by the Research Trust of Victoria University of Wellington. Our consolidated revenue sources and expenditure areas as well as five year summaries are summarized in the following charts (all figures are exclusive of GST). These charts combine the Centre and all grant budgets together.

In 2018, the ARC received a total of $4.37M in revenue and contributed $571K of overheads to the University, with a corresponding expenditure of $4.02M. The Centre budget made a small $5K surplus.

REVENUE

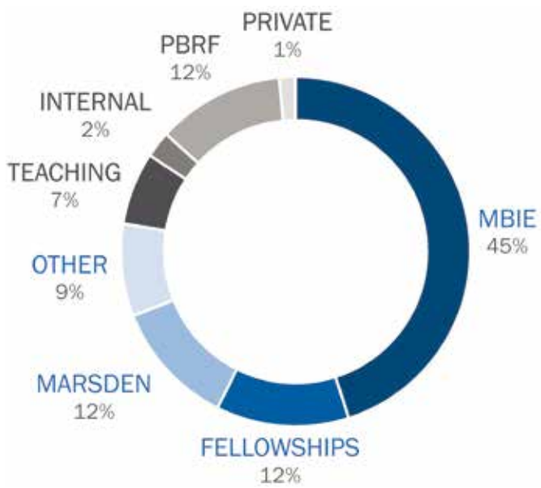
The ARC received 78% of its $4.37M of funding from external sources. Almost $2M of this came from the Ministry of Business, Innovation and Employment (MBIE) through our research programmes such as NZ SeaRise, and via sub-contracts with our research partners such as the Past Antarctic Climates (PAC) programme with GNS Science and Deep South National Science Challenge project with NIWA. The PAC programme sub-contract,worth $496K pa, which has been the financial backbone of the ARC since 2010, finally ended in September 2018.

The 12% Fellowship funding came from two Rutherford Fellowships and a James Cook Fellowship that ended in August 2018. The ARC had six active Marsden grants contributing $507K, four had ARC researchers as the PI and two were sub-contracts. The remaining 9% of external revenue came from New Zealand Antarctic Research Institute (NZARI) funding ($126K), the International Cables Protection Committee ($55K), and other national and international organisations ($48K).

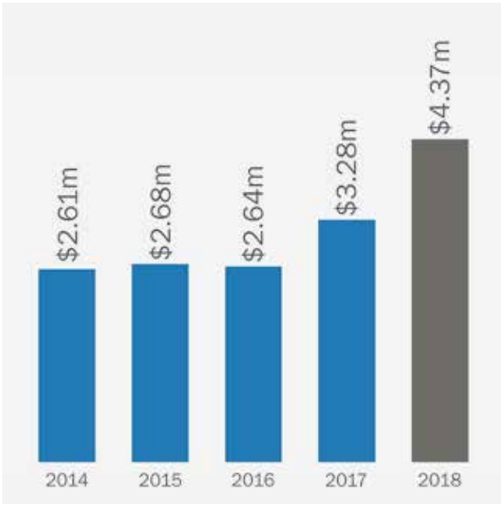
The remaining 22% of revenue comes from internal sources. The highest portion ($514K) is from PBRF (Performance-Based Research Fund) calculated by Victoria University for funding it receives based on the quality rating of our staff. The 9% teaching portion was the transfer of $293K from the School of Geography, Environment and Earth Sciences for teaching in their courses and a proportion of the supervision and PBRF graduate completion income for postgraduate students our academics supervised. Internal funding includes University funded grants such as the Faculty Strategic Research Grants which seven of our PhD student were awarded in 2018. Private revenue is the interest received from private donations held by the Victoria Foundation and transferred as grants for the ARC Endowed Development Fund.

The ARC was also awarded new fundng in 2018. Rob McKay successfully secured a $960K Marsden to begin in 2019. Shaun Eaves was awarded a British Society of Geomorphology grant of $6.5K for a small field-based preliminary project. ARC/SGEES PhD student Ross Whitmore received a $10K Antarctic Science Bursary from the UK based charitable company Antarctic Science Ltd which support promising early career scientists worldwide. Finally, SGEES/ ARC PhD student Florence Isaac received an Antarctica New Zealand scholarship for her research on sea ice.

2018 revenue



revenue five year summary



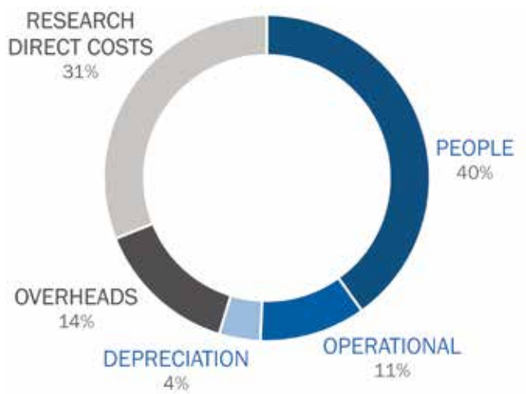
EXPENDITURE

In 2018, the ARC's expenditure costs included 40% of people related costs ($1.6M) associated with salaries, promotions, annual leave and superannuation. The ARC has 16 academic staff, two technical staff and two administration staff on permanent contracts as well as employing research fellows, research assistants and casual staff on temporary contracts. Near the end of 2018, ARC welcomed two new staff, Associate Professor Richard Levy and Research Fellow Stefan Jendersie.

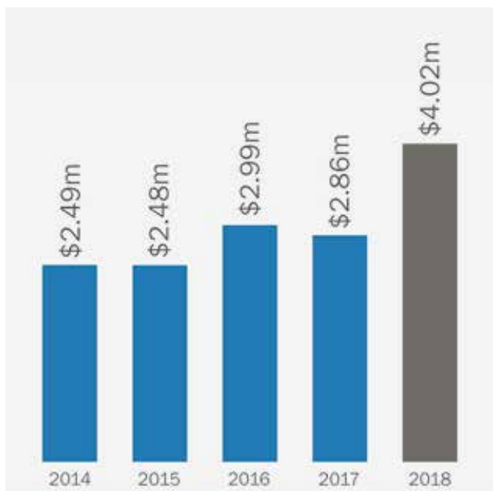
The research direct costs of 31% related to costs directly spent from our research grants. Of the $1.2M spent, $758K went towards paying sub-contracts to our research partners such as GNS Science, NIWA, University of Otago and University of Canterbury and $235K was used to support student fees and stipends. The 14% overheads was the $571K contribution from research grants to the Research Office and University.

The Centre's operational budget of $270K included $153K for office/storage space, $72K of expenditure which was later reimbursed from external organisations or transferred back to research grants, and and $15K for leasing computers and phone costs both charged by the University. Our storage costs were significantly reduced in 2018 by $46K by consolidating equipment previously stored in Te Aro, Karori and Kelburn campuses into a new lower cost facility in Lower Hutt. The final 4% costs are associated with the depreciation of CAPEX equipment. The 2018 amount of $165K was similar to the previous year despite new purchases in 2018 due to some of the Hot Water Drill parts such as the generators being written-off as they were not fit for purpose.

2018 expenditure



expenditure five year summary



PHD STUDENT WINS ANTARCTICA NEW ZEALAND SCHOLARSHIP

PhD student Florence Isaacs was one of three candidates to receive a 2018 Antarctica New Zealand scholarship for research on Antarctica and the Southern Ocean.

Florence, who is undertaking her studies with James Renwick (SGEES) and Andrew Mackintosh (ARC), says the scholarship will give her opportunities to go to Antarctic conferences and science summer schools, as well as travel to Antarctica.

“I hope this is the beginning of a long relationship with Antarctic research,” Florence says. “It’s incredibly exciting to be given the opportunity to achieve one of my lifelong dreams.”

“I had a really amazing Geography department at my high school (Wellington High School) which really gave me the drive to focus on environmental science, and eventually Antarctic science” she said.

Florence studied a Bachelor of Science in Geography at University of Otago, including a year at Durham University in the UK. Her PhD research is looking at changes in sea ice and outlet glaciers in East Antarctica and how they’re linked to changes in long-term climate patterns.

Florence’s project uses pre-existing data sets – so she’s mainly sitting at her computer running calculations and models. But part of this scholarship award involved her travelling to Antarctica in November 2018 to work in the field with NIWA scientist Natalie Robinson to study how sea ice in McMurdo Sound interacts with the upper ocean.

“Being able to experience this unique environment up close and personal gave me a greater understanding of processes that I’m currently only experiencing through data sets.”

The scholarship will also give her opportunities to go to Antarctic conferences and science summer schools.

Florence was also a recipient of an ARC Endowed Development Fund, to attend the highly competitive Karthaus Summer School on Ice and Climate, run by the Institute of Marine and Atmospheric Research, Utrecht. The school provides a basic introduction to the dynamics of glaciers and ice sheets, for around 40 early- stage PhD students from around the world.

“Before starting this research I had very little background in glaciology, so the Karthaus Summer School really helped to bridge a gap in my knowledge, and expand the possibilities of my research. I hope to incorporate many of the tools and skills that I gained into my final thesis,” said Florence.

Florence Isaacs on traverse to McMurdo Sound, Antarctica

Rob McKay

MORE SUCCESS FOR ARC RESEARCHER

Rob McKay has been awarded a Marsden Fund grant for his research on Antarctic ice sheet-ocean interactions.

Rob is among 22 successful Victoria University-led projects and will receive $960,000 over three-years, administered by the Royal Society Te Apārangi.

Rob’s research is looking into the marine-based West Antarctic Ice Sheet which is currently experiencing accelerated, and potentially irreversible retreat. This reflects shifts in wind-driven oceanic currents that are transporting warm waters towards the ice margin. While sea-level rise is the obvious impact of ice sheet melt, one of the largest unknowns is the role that ocean-ice sheet interactions may play in either dampening or amplifying future climate change.

“Our aim is to improve knowledge of the magnitude of ice sheet-ocean interactions during large (>2ºC) global climate changes in the geological past, when the Antarctic ice sheet partially retreated” said Rob.

Arnold Heine on the North Victoria Land traverse in 1959 - Photo: Arnold Heine

NZ & ANTARCTIC GLACIOLOGIST ARNOLD HEINE DONATES TO THE ARC

The Arnold Heine Antarctic Research Award was established in 2018 with a generous donation from Arnold Heine toward supporting future generations of Antarctic researchers.

Arnold Heine began his career as an Antarctican with the Department of Scientific and Industrial Research (DSIR) during the first IGY year. Originally selected to spend the 1958 winter at Scott Base, he headed south in December 1956 to familiarise himself with all “things” Antarctic before returning to spend 1957 in New Zealand planning the logistics, however, he ended up on the 1957/58 New Zealand Geological Survey (NZGS) Tucker Glacier Expedition. He returned the following summer as a member of the NZGS Wood Bay Expedition, and while at Scott Base had the opportunity to work with the resident US glaciologist, Al Stuart. Learning the skills of interpreting the annual layering of snow pit stratigraphy proved useful in collecting nuclear fallout samples for Athol Rafter, Director of DSIR Nuclear Sciences. It also saw the beginning of the McMurdo Ice Shelf Project. After spending the 1959 winter at Scott Base, he joined an international team for a traverse of North Victoria Land as assistant glaciologist. He transferred to the new Antarctic Division of the DSIR in 1962 as the Field Officer. In addition he organised the building of the Onyx River dam in the Wright Valley and the associated flow measurement of the Onyx River.

For his work in the Antarctic he was awarded the Polar Medal in 1969. Later he was part of the team to measure the effect of heavy loading on sea ice. After retiring in 1970 he continued working until 2016 as Secretary of the Trans Antarctic Association NZ that allocates funds to aspiring Antarctic researchers.

The Arnold Heine Antarctic Research Award will be awarded for the first time in 2019 in conjunction with the ARC Endowed Development Fund awards. Funding will be considered for any Victoria postgraduate students studying a topic related to the Antarctic region or glaciology in New Zealand. The fund will be held as an endowment by the Victoria University of Wellington Foundation.

ARC ENDOWED DEVELOPMENT FUND

Through the dedication and generosity of past and present staff, alumni, colleagues and collaborators the ARC has awarded more than $200,000 in scholarship funding to date.

The ARC Endowed Development Fund enables the ARC to give small grants of up to $4000 to postgraduate students with research links to Antarctica. This provides students with some amazing opportunities that would not have otherwise been possible. Examples include; participation in international summer schools, 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.

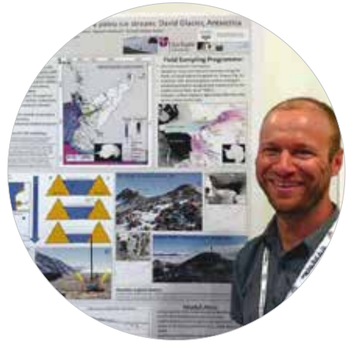
The 2018 recipients were:

Marjolaine Verret — to attend the Cryospheric Modelling course in Hokkaido, Japan in June.

Lukas Eling, Katelyn Johnson, Dan Lowry, Jamey Stutz, Abhijith Ulayottil Venugoapl, Laurine van Haastrecht and Ross Whitmore — to attend the SCAR/IASC Open Science: Polar2018 Conference in Davos, Switzerland in June.

Florence Isaacs — to attend the highly competitive Karthaus Ice and Climate Summer School in Italy in September.

Hannah Chorley and Georgia Grant — to present at the American Geophysical Union (AGU) Fall Meeting in Washington D.C., USA in December.



Jamey Stutz at Polar2018, Davos

ENGAGEMENT & OUTREACH

Photo: Dan Zwartz

ENGAGEMENT & OUTREACH

The ARC is committed to presenting our research and knowledge to the wider community. Here are a selection of our contributions.

TV INTERVIEWS

TVNZ One News — 7 January, Rob McKay "Large climate change expedition to set sail for Antarctica."

Newsroom — 18 January, Rob McKay "What would happen if the ice sheets melt." https://www.newsroom.co.nz/@future-learning/2018/01/17/75398/what-would-happen-if-the-ice-sheets-melt

Newsroom — 18 February, Tim Naish "Alarming projections for polar ice sheets." https://www.newsroom.co.nz/@future-learning/2018/02/27/92887/alarming-projections-for-polar-ice-sheets

TV3 NewsHub — 9 March, Rob McKay "NZ scientists drill 700 metres into Antarctic ice to study climate change." http://www.newshub.co.nz/home/new-zealand/2018/03/nz-scientists-drill-700-metres-into-antarctica-ice-to-study-climate-change.html

TVNZ One News — 9 May, Tim Naish "Should all Wellington ratepayers fork out for sea walls that protect only a few homes?"

Newshub — 11 May, Brian Anderson "New Zealand's glaciers ravaged by savage summer." http://www.newshub.co.nz/home/new-zealand/2018/05/new-zealand-s-glaciers-ravaged-by-savage-summer.html

Newsroom — 24 May, Huw Horgan "Five minutes with: An ice scientist." https://www.newsroom.co.nz/2018/05/23/110810/five-minutes-with-an-ice-scientist

TVNZ Breakfast News — 15 June, Nick Golledge "New study shows humanity must dramatically change its trajectory to halt Antarctic ice loss." https://www.tvnz.co.nz/one-news/new-zealand/new-study-shows-humanity-must-dramatically-change-its-trajectory-halt-antarctic-ice-loss?variant=tb_v_1

Newshub — 13 November, Tim Naish, Rob McKay "Paris Agreement regulations won't stop ice sheet collapse – report." https://www.newshub.co.nz/home/world/2018/11/paris-agreement-regulations-won-t-stop-ice-sheet-collapse-report.html

RADIO INTERVIEWS

ABC radio (Australia) — 12 January, Rob McKay "IODP expedition."

Radio Kidnappers (NZ) — 18 January, Rob McKay "Ship to shore."

Radio NZ 'Nine to Noon' — 13 February, Brian Anderson "Fast forward frames of glacial retreat." https://www.radionz.co.nz/national/programmes/ninetonoon/audio/2018631831/brian-anderson-fast-forward-frames-of-glacial-retreat

Radio NZ 'News' — 23 February, Tim Naish "Pacific Climate Change conference hears sea-level rise of two metres by 2100." https://www.radionz.co.nz/international/pacific-news/351090/pacific-climate-change-conference-hears-sea-level-rise-of-two-metres-by-2100

Radio NZ 'Our Changing World' — 15 March, Andrew Lorrey (NIWA), Andrew Mackintosh, Brian Anderson, Huw Horgan, Lauren Vargo "Glaciers in trouble after marine heatwave." https://www.radionz.co.nz/national/programmes/ourchangingworld/audio/2018635886/glaciers-in-trouble-after-marine-heatwave

NewsTalk ZB — 14 June, Nick Golledge "Antarctica melt will have major impact on humans."

Radio NZ 'Our Changing World' — 21 June 2018, Rob McKay "Antarctica's ice is melting." http://www.radionz.co.nz/national/programmes/ourchangingworld/audio/2018649941/antarctica-s-ice-is-melting

Radio NZ "Sunday Morning" — 24 June, Tim Naish "Tim Naish says we can still save Antarctic ice." https://www.radionz.co.nz/national/programmes/sunday/audio/2018650659/tim-naish-says-we-can-still-save-antarctic-ice

Radio NZ 'News' — 9 October, Tim Naish "Climate target not viable for NZ economy – expert" https://www.radionz.co.nz/news/national/368231/climate-target-not-viable-for-nz-economy-expert

Radio NZ 'Our Changing World' — 8 November, Andrew Mackintosh "Old ice gives insights into future sea level rise." https://www.radionz.co.nz/national/programmes/ourchangingworld/audio/2018669990/old-ice-gives-insights-into-future-sea-level-rise

NewsTalk ZB — 13 November, Nick Golledge "Can the world stop polar ice sheets collapsing?"

Newstalk ZB 'PHOTOS' — Brian Anderson "Iconic South Island glaciers retreating." http://www.newstalkzb.co.nz/photos/national/photos-iconic-south-island-glaciers-retreating/

NEWSPAPER/MAGAZINE ARTICLES

North and South Magazine — January, Rob McKay "Expedition South."

NZ Herald — 4 January, Rob McKay "International scientific research ship *JOIDES Resolution* tackles Zealandia mission." http://www.nzherald.co.nz/nz/news/article.cfm?c_id=1&objectid=11969693

Stuff — 4 January, Rob McKay "Science ship in Lyttelton: Lots of research from NZ's small contribution." https://www.stuff.co.nz/science/100304858/science-ship-in-lyttelton-lots-of-research-from-nzs-small-contribution

Stuff — 5 January, Tim Naish "Living on the Edge: What climate change means for Taranaki." https://www.stuff.co.nz/environment/98838911/living-on-the-edge-what-climate-change-means-for-taranaki

Gisbourne Herald — 8 January, Rob McKay "*JOIDES Resolution* heads to Antarctica." http://gisborneherald.co.nz/localnews/3172127-135/joides-resolution-heads-to-antarctica

NZ Listener — 26 January, Nick Golledge "Hot and bothered."

NZ Herald — 8 March, Andrew Lorrey (NIWA), Brian Anderson, Andrew Mackintosh, Huw Horgan and Lauren Vargo "What did NZ's hottest summer do to our glaciers?" https://www.nzherald.co.nz/nz/news/article.cfm?c_id=1&objectid=12008908

NZ Herald — 9 March, Rob McKay "Scientists break ice, and records, to gain climate clues." http://www.nzherald.co.nz/nz/news/article.cfm?c_id=1&objectid=12009791

Stuff — 9 March, Andrew Lorrey (NIWA), Brian Anderson, Andrew Mackintosh, Huw Horgan and Lauren Vargo "NZ glaciers looking 'sad and dirty' ahead of Niwa's annual aerial glacier survey." https://www.stuff.co.nz/environment/climate-news/102123604/nz-glaciers-looking-sad-and-dirty-ahead-of-niwas-annual-aerial-glacier-survey

Otago Daily Times — 10 March, Andrew Mackintosh "Glaciers 'pathetic' after heatwave." https://www.odt.co.nz/regions/west-coast/glaciers-'pathetic'-after-heatwave

Stuff — 13 March, Rob McKay "Antarctic expedition could help scientists uncover secret of melting ice sheets." https://www.stuff.co.nz/environment/102210463/antarctic-expedition-could-help-scientists-uncover-secret-of-melting-ice-sheets

NZ Herald — 19 April, Tim Naish "Scientists discover new melting process in Antarctica." https://www.nzherald.co.nz/nz/news/article.cfm?c_id=1&objectid=12035777

Wilderness Magazine — May 2018, Brian Anderson "Backcountry Meltdown."

NZ Herald — 5 May, Nancy Bertler "When warm winds blow in Antarctica's dark, freezing winter." https://www.nzherald.co.nz/nz/news/article.cfm?c_id=1&objectid=12044413

Otago Daily Times — 12 May 2018, Brian Anderson "Southern glaciers shrink after summer heatwave." https://www.odt.co.nz/news/national/southern-glaciers-shrink-after-summer-heatwave

The Conversation — 8 June, Andrew Lorrey (NIWA), Andrew Mackintosh, Huw Horgan, Lauren Vargo, Brian Anderson "A bird's eye view of New Zealand's changing glaciers." https://theconversation.com/a-birds-eye-view-of-new-zealands-changing-glaciers-97074

NZ Herald — 14 June, Tim Naish "Antarctica had lost three trillion tonnes of ice in less than three decades." https://www.nzherald.co.nz/nz/news/article.cfm?c_id=1&objectid=12069988

Stuff — 14 June, Tim Naish "'Grim future' on the horizon as Antarctic ice melt triples." https://www.stuff.co.nz/environment/104687180/grim-future-on-the-horizon-as-antarctic-ice-melt-triples

The Press — 14 June, Tim Naish "Antarctic ice sheet may be runaway." https://www.pressreader.com/

Stuff — 12 July, Tim Naish and James Renwick (SGEES) "Businesses band together to tackle climate change." https://www.stuff.co.nz/business/105398439/businesses-band-together-to-tackle-climate-change

North and South — July, Rob McKay "Core! Cutting edge science meets high adventure in Southern Hemisphere waters."

Deutsche Welle — 2 August, Brian Anderson "Living Planet: Bye-bye, glacier tourism?" https://www.dw.com/en/living-planet-bye-bye-glacier-tourism/av-44924139

Stuff — 20 August, Shaun Eaves "GNS Science unveils new explanation for volcanic forms in the Tongariro National Park with new geological map." https://www.stuff.co.nz/science/106413587/gns-science-unveils-new-explanation-for-volcanic-forms-in-the-tongariro-national-park-with-new-geological-map

Deutsche Welle — 30 August, Brian Anderson "The frozen tears of New Zealand's melting glaciers." https://www.dw.com/en/the-frozen-tears-of-new-zealands-melting-glaciers/a-44910628

NZ Listener — 29 September, Tim Naish "The impact rising sea levels will have on New Zealand." https://www.noted.co.nz/currently/science/rising-sea-levels-new-zealand-impact/

Otago Daily Times — 9 October, Tim Naish "Climate target not viable for NZ economy." https://www.odt.co.nz/news/national/rnz/climate-target-not-viable-nz-economy

NZ Herald — 13 November, Nick Golledge, Rob McKay, Tim Naish "Can the world stop polar ice sheets collapsing?" https://www.nzherald.co.nz/nz/news/article.cfm?c_id=1&objectid=12159189

NZ Listener — 17 November, Tim Naish "Rising sea levels are putting our coasts in crisis – should we adapt or retreat." https://www.noted.co.nz/planet/rising-sea-levels-coasts-crisis-heres-what-we-can-do/

NZ Herald — 6 December, Tim Naish "Into the ice world: Why we should all care about Antarctica." https://www.nzherald.co.nz/nz/news/article.cfm?c_id=1&objectid=12170458

Stuff — Brian Anderson "Thin Ice." https://interactives.stuff.co.nz/2018/04/thin-ice/

TALKS TO POLICYMAKERS

Pacific Climate Change Conference — 22 February, Tim Naish "Future ice sheet contribution to sea-level rise."

New Zealand Institute of International Affairs — 27 February, Tim Naish "Climate change."

Speaker's Science Forum — 13 June, Rob McKay talk to parliament.

Minister David Parker, and EU Trade Commissioner Malmstrom — 22 June 2018, Rob McKay

Department of Conservation — 5 September, Andrew Mackintosh and Brian Anderson "Glacier retreat and impacts with a focus on kā tiritiri-o-te-moana (the NZ Southern Alps)."

Minister for Climate Change James Shaw — 16 November 2018, Nick Golledge.

SCHOOL & COMMUNITY GROUPS

Letters to a Pre-scientist Pen-pal Program — Dan Lowry.

Worcester Polytechnic Institute — 17 January-27 February, Ross Whitmore, Shaun Eaves, and Jamey Stutz.

Wellington Tramping and Mountaineering Club — 31 January, Ross Whitmore "Ice surface changes in Antarctic outlet glaciers through time."

Amundsen Exhibition Talks — 19 February, Tim Naish and James Renwick (SGEES) "A race to save the pole - a scientist's view."

The Nature Conservancy Symposium — 12 March, Tim Naish "Influence of climate change on the Southern Ocean and Ross Sea marine protected area."

U3A Waikanae — 12 March, Nancy Bertler "Global sea-level rise - Impact on New Zealand's shores."

New Zealand Antarctic Society — 22 March, Jamey Stutz "Recent deglacial history of the David Glacier, North Victoria Land."

Catawba Springs and Gros Cap Elementary — 10 April & 28 May, Jamey Stutz.

Puke Ariki New Plymouth — 23 May, James Renwick (SGEES) and Tim Naish.

Gros Cap Elementary — 4 June, Jamey Stutz.

Island Bay School — 13 September, Gavin Dunbar, Dao Polsiri and Jamey Stutz.

U3A Lower Hutt — 12 November, Nancy Bertler "60 years of NZ Science Endeavour in Antarctica."

Antarctic Science Bursary Writing Mentor — 2 October, Ross Whitmore.

New Zealand Antarctic Society — 29 November, Nancy Bertler "Antarctic Science Platform - Vision for the Future."

Skype a Scientist (Colorado Springs, USA) — 12 December, Ross Whitmore.

Science Media Centre — 17 December, Nick Golledge "Scientists' advice for climate action – Expert Q&A."

Track Zero Arts and Climate Science Road Show — 4 lectures, Tim Naish, James Renwick (SGEES) and Sarah Meads.

PUBLICATIONS & CONFERENCES

Photo:SCAR

PUBLICATIONS

PEER-REVIEWED PUBLICATIONS

Anacona, P.I., Norton, K., **Mackintosh**, A., Escobar, F., Allen, S., Mazzorana, B., Schaefer, M. (2018). Dynamics of an outburst flood originating from a small and high-altitude glacier in the Arid Andes of Chile. *Natural Hazards* 94(1): 93-119. doi:10.1007/s11069-018-3376-y

Armbrecht, L.H., Lowe, V., Escutia, C., Iwai, M., **McKay**, R., Armand, L.K. (2018). Variability in diatom and silicoflagellate assemblages during Mid-Pliocene glacial-interglacial cycles determined in hole U1361a of IODP Expedition 318, Antarctic Wilkes Land Margin. *Marine Micropaleontology* 139: 28-41. doi.org/10.1016/j.marmicro.2017.10.008

Bertler, N.A.N., Conway, H., Dahl-Jensen, D., Emanuelsson, D.B., Winstrup, M., Vallelonga, P.T., Lee, J.E., Brook, E.J., Severinghaus, J.P., Fudge, T.J., Keller, E.D., Baisden, W.T., Hindmarsh, R.C.A., Neff, P.D., Blunier, T., Edwards, R., Mayewski, P.A., Kipfstuhl, S., Buizert, C., Canessa, S., Dadic, R., Kjær, H.A., Kurbatov, A., Zhang, D., Waddington, E.D., Baccolo, G., Beers, T., Brightley, H.J., **Carter**, L., Clemens-Sewall, D., Ciobanu, V.G., Delmonte, B., Eling, L., Ellis, A., Ganesh, S., **Golledge**, N.R., Haines, S., Handley, M., Hawley, R.L., Hogan, C.M., **Johnson**, K.M., Korotkikh, E., **Lowry**, D.P., **Mandeno**, D., **McKay**, R.M., Menking, J.A., **Naish**, T.R., Noerling, C., Ollive, A., Orsi, A., Proemse, B.C., **Pyne**, A.R., Pyne, R.L., Renwick, J., Scherer, R.P., Semper, S., Simonsen, M., Sneed, S.B., Steig, E. J., Tuohy, A., **Venugopal**, A.U., Valero-Delgado, F., Venkatesh, J., Wang, F., Wang, S., Winski, D.A., Winton, V.H.L., Whiteford, A., Xiao, C., Yang, J., Zhang, X. (2018). The Ross Sea Dipole – temperature, snow accumulation and sea ice variability in the Ross Sea region, Antarctica, over the past 2700 years. *Climate of the Past* 14: 193-214. doi:10.5194/cp-14-193-2018

Bertram, R.A., Wilson, D.J., van de Flierdt, T., **McKay**, R.M., Patterson, M.O., Jimenez-Espejo, F.J., Escutia, C., Duke, G.C., Taylor-Silva, B.I., Riesselman, C.R. (2018). Pliocene deglacial event timelines and the biogeochemical response offshore Wilkes subglacial basin, East Antarctica. *Earth and Planetary Science Letters* 494: 109-116. doi.org/10.1016/j.epsl.2018.04.054

Bostock, H., Jenkins, C., Mackay, K., **Carter**, L., Nodder, S., Orpin, A., Pallentin, A., Wysoczanski, R. (2018). Distribution of surficial sediments in the ocean around New Zealand/Aotearoa. Part A: continental slope and deep ocean. New Zealand *Journal of Geology and Geophysics*. doi: 10.1080/00288306.2018.1523198 (published online 01 Oct 2018)

Bostock, H., Jenkins, C., Mackay, K., **Carter**, L., Nodder, S., Orpin, A., Pallentin, A., Wysoczanski, R. (2018). Distribution of surficial sediments in the ocean around New Zealand/Aotearoa. Part B: continental shelf. *New Zealand Journal of Geology and Geophysics*. doi: 10.1080/00288306.2018.1523199 (published online 01 Oct 2018)

Colleoni, F., De Santis, L., Siddoway, C.S., Bergamasco, A., **Golledge**, N.R., Lohmann, G., Passchier, S., Siegert, M.J. (2018). Spatio-temporal variability of processes across Antarctic ice-bed–ocean interfaces. *Nature Communications* 9: 2289. doi.org/10.1038/s41467-018-04583-0

Eaves, S.R., Collins, J.A., Jones, R.S., Norton, K.P., Tims, S.G., **Mackintosh**, A.N. (2018). Further constraint of the in situ cosmogenic 10Be production rate in pyroxene and a viability test for late Quaternary exposure dating. *Quaternary Geochronology* 48: 121-132. doi:10.1016/j.quageo.2018.09.006

Emanuelsson, B.D., **Bertler**, N.A.N., Neff, P.D., Renwick, J.A., Markle, B.R., Baisden, W.T., Keller, E.D. (2018). The role of Amundsen-Bellingshausen Sea anticyclonic circulation in forcing marine air mass intrusions into West Antarctica. *Climate Dynamics* 51(9-10): 3579-3596. doi:10.1007/s00382-018-4097-3

Goelzer, H., and 30 co-authors incl. **Golledge**, N.R. (2018). Design and results of the ice sheet model initialisation initMIP-Greenland: an ISMIP6 intercomparison. *The Cryosphere* 12: 1433-1460. doi.org/10.5194/tc-12-1433-2018

Grant, G.R., Sefton, J.P., Patterson, M.O., **Naish**, T.R., **Dunbar**, G.B., Hayward, B.W., Morgans, H.E.G., Alloway, B.V., Seward, D., Tapia, C.A., Prebble, J.G., Kamp, P.J.J., **McKay**, R., Ohneiser, C., Turner, G.M. (2018). Mid-to Late Pliocene (3.3-2.6 Ma) global sea-level fluctuations recorded on a continental shelf transect, Whanganui Basin, New Zealand. *Quaternary Science Reviews* 201: 241-260. doi.org/10.1016/j.quascirev.2018.09.044

Keller, E.D., Baisden, W.T., **Bertler**, N.A.N., Emanuelsson, B.D., Canessa, S., Phillips, A. (2018). Calculating uncertainty for the RICE ice core continuous flow analysis water isotope record. *Atmospheric Measurement Techiques* 11: 4725-4736. doi:10.5194/amt-11-4725-2018

Kim, S., De Santis, L., Hong, J.K., Cottlerle, D., Petronio, L., Colizza, E., Kim, Y.-., Kang, S.-., Kim, H.J., Kim, S., Wardell, N., Geletti, R., Bergamasco, A., **McKay**, R., Jin, Y.K., Kang, S.-. (2018). Seismic stratigraphy of the Central Basin in Northwestern Ross Sea slope and rise, Antarctica: Clues to the Late Cenozoic ice-sheet dynamics and bottom-current activity. *Marine Geology* 395: 363-379. doi.org/10.1016/j.margeo.2017.10.013

Kraus, C. and **Carter**, L. (2018). Seabed recovery following protective burial of subsea cables - Observations from the continental margin. *Ocean Engineering* 157: 251-261.

Levy, R.H., **Dunbar**, G.B., Vandergoes, M.J., Howarth, J.D., Kingan, T., **Pyne**, A.R., Brotherston, G., Clarke, M., Dagg, B., Hill, M., Kenton, E., Little, S., **Mandeno**, D., Moy, C., Muldoon, P., Doyle, P., Raines, C., Rutland, P., Strong, D.T., Terezow, M., Cochrane, L., Cossu, R., Fitzsimons, S., Florindo, F., Forrest, A.L., Gorman, A.R., Kaufman, D.S., Lee, M.K., Li, X., Lurcock, P., McKay, N., Nelson, F., Purdie, J., Roop, H.A., Schladow, S.G., Sood, A., Upton, P., Walker, S.L., Wilson, G.S. (2018). A high-resolution climate record spanning the past 17 000 years recovered from Lake Ohau, South Island, New Zealand. *Scientific Drilling* 24: 41-50. doi.org/10.5194/sd-24-41-2018

Lowry, D.P., and Morrill, C. (2018). Is the Last Glacial Maximum a reverse analog for future hydroclimate changes in the Americas? *Climate Dynamics* 1-21. doi: 10.1007/s00382-018-4385-y

McKay, R.M., De Santis, L., Kulhanek, D.K., and the Expedition 374 Scientists (2018). Expedition 374 Preliminary Report: Ross Sea West Antarctic Ice Sheet History. *International Ocean Discovery Program* 374. https://doi.org/10.14379/iodp.pr.374.2018

McKay, R., Exon, N., Müller, D., Gohl, K., Gurnis, M., Shevenell, A., Henrys, S., Inagaki, F., Pandey, D., Whiteside, J., Van De Flierdt, T., **Naish**, T., Heuer, V., Morono, Y., Coffin, M., Godard, M., Wallace, L., Kodaira, S., Bijl, P., Collot, J., Dickens, G., Dugan, B., Dunlea, A.G., Hackney, R., Ikehara, M., Jutzeler, M.,

Mcneill, L., Naik, S., Noble, T., Opdyke, B., Pecher, I., Stott, L., Uenzelmann-Neben, G., Vadakkeykath, Y., Wortmann, U.G. (2018). Developing community-based scientific priorities and new drilling proposals in the Southern Indian and Southwestern Pacific oceans. *Scientific Drilling* 24: 61-70. doi.org/10.5194/sd-24-61-2018

Morril, C., **Lowry**, D.P., and Hoell, A. (2018). Thermodynamic and dynamic causes of pluvial conditions during the Last Glacial Maximum in western North America. *Geophysical Research Letters* 45(1): 335-345. doi: 10.1002/2017GL075807

Mountjoy, J.J., Howarth, J.D., Orpin, A.R., Barnes, P.M., Bowden, D.A., Rowden, A.A., Schimel, A.C.G., Holden, C., **Horgan**, H.J., Nodder, S.D., Patton, J.R., Lamarche, G., Gerstenberger, M., Micallef, A., Pallentin, A., Kane, T. (2018). Earthquakes drive large-scale submarine canyon development and sediment supply to deep-ocean basins. *Science Advances* 4(3): 1-8. doi:10.1126/sciadv.aar3748

Pant, N.C., Jimenez-Espejo, F.J., Cook, C.P., Biswas, P., **McKay**, R., Marchesi, C., Ito, M., Upadhyay, D., Kuroda, J., Shimizu, K., Senda, R., Van De Flierdt, T., Takano, Y., Suzuki, K., Escutia, C., Shrivastava, P.K. (2018). Suspected meteorite fragments in marine sediments from East Antarctica. *Antarctic Science* 30(5): 307-321. doi.org/10.1017/S0954102018000299

Patterson, M.O., **McKay**, R., **Naish**, T., Bostock, H.C., Dunbar, R., Ohneiser, C., Woodard, S.C., Wilson, G., Caballero-Gill, R. (2018). A Southwest Pacific perspective on long-term global trends in Pliocene-Pleistocene stable isotope records. *Paleoceanography and Paleoclimatology* 33(7): 825-839. doi.org/10.1029/2017PA003269

Pattyn, F., Ritz, C., Hanna, E., Asay-Davis, X., DeConto, R., Durand, G., Favier, L., Fettweis, X., Goelzer, H., **Golledge**, N.R., Munneke, P. K., Lenaerts, J.T.M., Nowicki, S., Payne, A.J., Robinson, A., Seroussi, H., Trusel, L.D., van den Broeke, M. (2018). The Greenland and Antarctic ice sheets under 1.5°C global warming. *Nature Climate Change* 8: 1053-1061. doi:10.1038/s41558-018-0305-8

Purdie, H., **Anderson**, B., **Mackintosh**, A., Lawson, W. (2018). Revisiting glaciological measurements on Haupapa/Tasman Glacier, New Zealand, in a contemporary context. *Geografiska Annaler: Series A, Physical Geography* 100(4): 351-369. doi:10.1080/04353676.2018.1522958

Pyne, R., Keller, E., Canessa, S., **Bertler**, N., **Pyne**, A., **Mandeno**, D., Vallelonga, P., Semper, S., Kjær, H., Hutchinson, E. (2018). A novel approach to process brittle ice for continuous flow analysis of stable water isotopes. *Journal of Glaciology* 64(244): 289-299. doi:10.1017/jog.2018.19

Rintoul, S.R., Chown, S.L., DeConto, R.M., England, M.H., Fricker, H.A., Masson-Delmotte, V., **Naish**, T.R., Siegert, M.J., Xavier, J.C. (2018). Choosing the future of Antarctica. *Nature* 558(7709): 233-241. doi:10.1038/s41586-018-0173-4

Salabarnada, A., Escutia, C., Röhl, U., Nelson, C.H., **McKay**, R., Jiménez-Espejo, F.J., Bijl, P.K., Hartman, J.D., Strother, S.L., Salzmann, U., Evangelinos, D., López-Quirós, A., Flores, J.A., Sangiorgi, F., Ikehara, M., Brinkhuis, H. (2018). Paleoceanography and ice sheet variability offshore Wilkes Land, Antarctica - Part 1: Insights from Late Oligocene astronomically paced contourite sedimentation. *Climate of the Past* 14(7): 991-1014. doi.org/10.5194/cp-14-991-2018

Sangiorgi, F., Bijl, P.K., Passchier, S., Salzmann, U., Schouten, S., **McKay**, R., Cody, R.D., Pross, J., Van De Flierdt, T., Bohaty, S.M., **Levy**, R., Williams, T., Escutia, C., Brinkhuis, H. (2018). Southern Ocean warming and Wilkes Land ice sheet retreat during the Mid-Miocene. *Nature Communications* 9(1): 317. doi: 10.1038/s41467-017-02609-7

Shakun, J.D., Corbett, L.B., Bierman, P.R., Underwood, K., Rizzo, D.M., Zimmerman, S.R., Caffee, M.W., **Naish**, T., **Golledge**, N.R., Hay, C.C. (2018). Minimal East Antarctic Ice Sheet retreat onto land during the past 8 million years. *Nature* 558(7709): 284-287. doi:10.1038/s41586-018-0155-6

Vandergoes, M.J., Howarth, J.D., **Dunbar**, G.B., Turnbull, J.C., Roop, H.A., **Levy**, R.H., Li, X., Prior, C.A., Norris, M.W., Keller, E.D., Baisden, W.T., Ditchburn, R.G., Fitzsimons, S.J., Bronk Ramsey, C. (2018). Integrating chronological uncertainties for laminated lake sediments. *Quaternary Science Reviews* 188: 104-120. doi: 10.1016/j.quascirev.2018.03.015

Vargo, L.J., Galewsky, J., Rupper, S., Ward, D.J. (2018). Sensitivity of glaciation in the arid subtropical Andes to changes in temperature, precipitation, and solar radiation. *Global and Planetary Change* 163: 86-96. doi: 10.1016/j.gloplacha.2018.02.006

Wilson, D.J., Bertram, R.A., Needham, E.F., Van De Flierdt, T., Welsh, K.J., **McKay**, R.M., Mazumder, A., Riesselman, C.R., Jimenez-Espejo, F.J., Escutia, C. (2018). Ice loss from the East Antarctic Ice Sheet during Late Pleistocene interglacials. *Nature* 561(7723): 383-386. doi: 10.1038/s41586-018-0501-8

BOOKS/MAPS

Allison, I., Hock, R., King, M.A., and **Mackintosh**, A.N. (2018). Future Earth and the cryosphere. In Beer, T., Li, J., Alverson, K., (Eds). *Global Change and Future Earth: The Geoscience Perspective 3* pg 91-113. Cambridge University Press, ISBN: 9781107171596

McKay, R. (2018). Sediment and Ice Cores (Past Polar Climates). Abingdon: Routledge Handbooks Online.

Townsend, D., Leonard, G.S., Conway, C.E., **Eaves**, S.R., Wilson, C.J.N. (2018). Geology of the Tongariro National Park Area [map]. Lower Hutt (NZ): GNS Science 1 sheet + 109 p., scale 1:60 000. (*GNS Science geological map; 4*).

Naish, T. (2018). Climate change In Nikkhou-O'Brien, M. (Ed), The Law of the Jungle: How Can New Zealand Navigate Global Disruption?. New Zealand Institute of International Affairs publication.

INVITED PRESENTATIONS, WORKSHOPS, AND STUDENT PRESENTATIONS

INVITED PRESENTATIONS

Bertler, N. (2018). Sea ice variability in the Ross Sea region - a longer term view from ice core records. *New Zealand Sea Ice Symposium*, Wellington, New Zealand, 5-6 July 2018.

Bertler, N.A.N., *et al*. (2018). Rapid Ross Sea deglaciation as captured in the RICE Ice Core. *American Geophysical Union*, Washington D.C., USA, 10-14 December 2018.

Carter, L. (2018). Submarine cables and the area beyond national jurisdiction. P*acific Telecommunications Council PTC Annual Meeting,* Hawaii, USA, 21 January 2018.

Carter, L. (2018). Climate change and submarine cables - an update for 2018. *International Cable Protection Committee*, Cape Town, South Africa, 9-12 April 2018.

Carter, L. (2018). Why study the New Zealand Quaternary? *GNS Science Quaternary Techniques Short Course*, GNS Science, Lower Hutt, New Zealand, 17 May 2018.

Carter, L. (2018). Cables and the marine environment – From ocean to cloud. 31 May 2018. *International webinar* https://www.iscpc.org/webinar/

Carter, L. (2018). Submarine communications cables - fault analysis. *Mathematics and Industry New Zealand Workshop,* AUT, Auckland, New Zealand, 25-29 June 2018.

Carter, L. (2018). Ocean Drilling Program - Pacific Gateway. Wellington Branch *Geoscience Society*, Wellington, New Zealand, 22 November 2018.

Dadic, R. (2018). From snowflakes to ice sheets: Why we need a multi-scale approach to understand past, present and future changes in the cryosphere. *EPFL (Swiss Federal Institute of Technology)*, Lausanne, Switzerland, 4 November 2018.

Eaves, S.R. (2018). Reconstructing climate using glaciers. *GNS Science Quaternary Techniques Short Course*, GNS Science, Lower Hutt, New Zealand, 18 May 2018.

Golledge, N. (2018). Ice sheets, climate, and sea-level, from the past to the future. *Australian National University*, Canberra, Australia, September 2018.

Golledge, N. (2018). Causes and consequences of 21st century ice sheet melt. *Geosciences Conference*, Napier, New Zealand, 27-30 November 2018.

Golledge, N. (2018). Ice sheet evolution in the past and into the future, and the role of interactions with the ocean. *National Institute of Polar Research 'Ice-Ocean Interactions' Workshop*. Tokyo, Japan, December 2018.

Mackintosh, A. (2018). Towards the detection and attribution of ice sheet changes to human and natural causes. *Institute of Marine and Southern Ocean Studies*, University of Tasmania, Australia, 16 April 2018.

Mackintosh, A. (2018). Climatic and ice-dynamic processes that limit the detection and attribution of Antarctic ice sheet changes. *International Workshop on Cryospheric Changes and their Regional and Global Impact*. Dunhuang, China, 30 July 2018.

Naish, T. and Grant, G. (2018). Meltwater contributions to Mid to Late Pliocene (3.3-2.6Ma) global sea-level. *SCAR/IASC Open Science Conference*, Davos, Switzerland, 20 June 2018.

Naish, T. (2018). Research School of Earth Sciences, *Australia National University*, Canberra, Australia, 19 July 2018.

Naish, T. (2018). New Zealand SeaRise Programme. *Australian Department of Environment and Energy*, Canberra, Australia, 23 July 2018.

CHAIRED WORKSHOPS

Bertler, N.A.N. (2018). *RICE Workshop*, University of Maine, Orono, USA, 16-18 May 2018.

Bracegirdle, T., Russell, J., **Bertler**, N., Khan, A. (2018). AntClim21 Past2Projections workshop. *SCAR/IASC Open Science Conference*, Davos, Switzerland, 16-17 June 2018.

Eaves, S.R. (2018). The multi-millennial context of present-day glacier retreat in New Zealand. *Snow and Ice Research Group (SIRG) annual meeting*, Methven, New Zealand, 7 February 2018.

Eaves, S.R. (2018). Alpine ICE-D database workshop. *Lawrence Livermore National Laboratory*, California, USA, 12 March 2018.

Eaves, S.R. (2018). Holocene glacier fluctuations in New Zealand. *Southern Hemisphere Assessment of Palaeoenvironments (SHAPE) Holocene workshop*, GNS Science, Avalon, New Zealand, 6 September 2018.

Naish, T. (2018). Polar science and policy — SCAR 60th Anniversary. *SCAR/IASC Open Science Conference*, Davos, Switzerland, 20 June 2018.

Stutz, J., (2018). Field work planning – panellist. *APECS World Summit*, Davos, Switzerland, 18 June, 2018.

Stutz, J. and Baroni, C. (2018). Glacial history Terra Nova Bay. *University of Pisa Collaborative Workshop*, Pisa, Italy, 3 July 2018.

Stutz, J., Baroni, C., and Lee, J. (2018). Glacial history Terra Nova Bay. *SCAR/IASC Open Science Conference Collaborative workshop*, Davos, Switzerland, 19 June 2018.

Vargo, L., **Anderson**, B., **Horgan**, H., **Mackintosh**, A., Lorrey, A., Thornton, M. (2018). Measuring New Zealand glacier fluctuations from historic photographs. *Snow and Ice Research Group Meeting*, Methven, New Zealand, 7-9 February 2018.

STUDENT ORAL PRESENTATIONS

Eling, L., **Bertler**, N.A.N., Lee, J., **McKay**, R., Pyne, R. (2018). Rapid end of the early Holocene climatic optimum in the Ross Sea region – New insights from the major ion record of the RICE ice core. *Geosciences Conference*, Napier, New Zealand, 27-30 November 2018.

Grant, G.R., **Naish**, T.R., **Dunbar**, G.B., Stocchi, P., Kominz, M.A., Kamp, P.J.J., **Levy**, R.H., **McKay**, R.A., Patterson, M.O. (2018). Sea level, ice sheet variability and climate forcing: a new sea level record (3.3-1.7 Ma). *Geosciences Conference*, Napier, New Zealand, 27-30 November 2018.

Grant, G.R., **Naish**, T.R., **Dunbar**, G.B., Stocchi, P., Kominz, M.A., Kamp, P.J.J., **Levy**, R.H., **McKay**, R.A., Patterson, M.O., Tapia, C. (2018). Global sea level during the mid to late Pliocene (3.3-2.6 Ma) and implications for polar ice sheet volume. *American Geophysical Union*, Washington D.C., USA, 10-14 December 2018.

Isaacs, F., Renwick, J., and **Mackintosh**, A. (2018). Largescale climate drivers of recent variability in sea ice concentration around East Antarctica. *New Zealand Sea Ice Symposium*, Wellington, 5-6 July 2018.

Isaacs, F., Renwick, J., and **Mackintosh**, A. (2018). Climate variability and cryospheric changes in East Antarctica, using satellite-era observational records and climate reanalysis data. *CLIVASH2k Workshop*, Cambridge, United Kingdom, 4-5 September 2018.

Johnson, K.M., **McKay**, R., Jiménez-Espejo, F.J., **Bertler**, N.A.N., Albot, A., Riesselman, C. (2018). Evaluating El Niño-Southern Oscillation signatures in offshore Adélie Land, East Antarctic sediment core. *Geosciences Conference*, Napier, New Zealand, 27-30 November 2018.

Lowry, D.P., **Golledge**, N.R., **Bertler**, N.A.N. (2018). Evolution of the Ross Ice Shelf since the Last Glacial Maximum. *SCAR/IASC Open Science Conference*, Davos, Switzerland, 19-23 June 2018.

Lowry, D.P., **Golledge**, N.R., Menviel, L., **Bertler**, N.A.N. (2018). Deglacial evolution of regional Antarctic climate and Southern Ocean conditions in climate simulations. *Geosciences Conference*, Napier, New Zealand, 27-30 November 2018.

Stutz, J. (2018). Rapid collapse of David Glacier during the last glacial termination. *Korea – New Zealand Bilateral Antarctic Cooperation Workshop*, Incheon, Korea, 15-18 October 2018.

Stutz, J., **Mackintosh**, A., Norton, K., **Whitmore**, R. (2018). Rapid collapse of David Glacier during the last glacial termination. *Geosciences Conference*, Napier, New Zealand, 27-30 November 2018.

Ulayottil Venugopal, A., **Bertler**, N.A.N., Lee, J.E., Cortese, G., Menviel, L., Pyne, R.L. (2018). Characterisation of AIM Events in the Ross Sea Region from the RICE ice core. *SCAR/IASC Open Science Conference*, Davos, Switzerland, 19-23 June 2018.

Ulayottil Venugopal, A., **Bertler**, N., Lee, J., Cortese, G., Pyne, R. (2018). Insights into the phasing and evolution of ocean bipolar see-saw from a new deep ice core record from Ross Sea region, West Antarctica. *Geosciences Conference*, Napier, New Zealand, 27-30 November 2018.

van Haastrecht, L.N., **Golledge**, N., and **Horgan**, H. (2018). Simplified flowline models of Kamb Ice Stream with differing subglacial conditions. *SCAR/IASC Open Science Conference*, Davos, Switzerland, 19-23 June 2018.

Whitmore, R., Jones, R., **Mackintosh**, A., Norton, K., **Eaves**, S. (2018). Rapid regional-scale ice-surface lowering at ~6.5 ka in southern Victoria Land, Antarctica. *Korea-New Zealand Bilateral Antarctic Cooperation Workshop,* 15 October 2018.

Whitmore, R., Jones, R., **Mackintosh**, A., Norton, K., **Eaves**, S. (2018). Rapid regional-scale ice-surface lowering at ~6.5 ka in southern Victoria Land, Antarctica. *Korea University Cosmo Laboratory Group*, 17 October 2018.

Whitmore, R., **Mackintosh**, A., Norton, K., Atkins, C., **Stutz**, J., Jones, R. (2018). New records of Holocene glacial fluctuations from Victoria Land, Antarctica. *SCAR/IASC Open Science Conference*, Davos, Switzerland, 19-23 June 2018.

Whitmore, R., **Mackintosh**, A., Norton, K., Atkins, C., **Stutz**, J., Jones, R. (2018). New record of ice surface elevation changes for tucker glacier in Victoria Land, Antarctica. *4th Annual Nordic Conference on Terrestrial Cosmogenic Nuclides*, 4-6 June 2018.

STUDENT POSTER PRESENTATIONS

Chorley, H., **Levy**, R., **Naish**, T., **Dickinson**, W., **Verret**, M., Hemming, S., Harper, M., Prebble, J., Ohneiser, C., **Duncan**, B., Halberstadt, A., Kowalewski, D., Florindo, F., Lurcock, P. (2018). Early to mid-Miocene East Antarctic Ice Sheet variability from the Friis Hills drilling project drillcore. *American Geophysical Union*, Washington D.C., USA, 10-14 December 2018.

Eling, L., **Bertler**, N.A.N., Lee, J.E., **McKay**, R.M., Pyne, R.L. (2018). Reconstruction of Early Holocene Environmental Conditions from the RICE Ice Core. *SCAR/IASC Open Science Conference*, Davos, Switzerland, 19-23 June 2018.

Eling, L., **Bertler**, N.A.N., Lee, J.E., **McKay**, R.M., Pyne, R.L. (2018). Rapid shift in centennial Antarctic climate variability during the Early Holocene - new evidence from the RICE Ice Core., *American Geophysical Union*, Washington D.C., USA, 10-14 December 2018.

Johnson, K.M., **McKay**, R., Jiménez-Espejo, F.J., **Bertler**, N.A.N., Albot, A. (2018). Characterizing Holocene climate variability from Adélie Basin sediment core. *SCAR/IASC Open Science Conference*, Davos, Switzerland, 19-23 June 2018.

Lowry, D.P., **Golledge**, N.R., **Bertler**, N.A.N. (2018). Integration of climate and ice sheet model simulations with the Roosevelt Island Climate Evolution (RICE) ice core record for the last deglaciation. *American Geophysical Union*, Washington D.C., USA, 10-14 December 2018.

Macklin, C., **Horgan**, H., and **Anderson**, B. (2018). Finite-element modelling of Tasman Glacier's basal sliding events. *Geosciences Conference*, Napier, New Zealand, 27-30 November 2018.

Pretty, R.F., **McKay**, R., **Dunbar**, G., **Naish**, T.R. (2018). Ice dynamics and ocean productivity during the Late Miocene offshore Wilkes Land, East Antarctica. *Geosciences Conference*, Napier, New Zealand, 27-30 November 2018.

Stutz, J., Grunow, A., Horn, J., Jaggi, J. (2018). Exposing students to polar scientific field work: Partnership, rocks & ECW. *SCAR/IASC Open Science Conference*, Davos, Switzerland, 19-23 June 2018.

Stutz, J., **Mackintosh**, A., Norton, K., **Whitmore**, R., Jamieson, S., Jones, R.S. (2018). Thinning history and modelling of a paleo ice stream: David Glacier, Antarctica. *SCAR/IASC Open Science Conference*, Davos, Switzerland, 19-23 June 2018.

Turton, N.A., **McKay**, R., **Dunbar**, G., **Naish**, T. (2018). Ice sheet and Southern Ocean response to orbital forcing during Early Pliocene warmth, Wilkes Land, East Antarctica. *Geosciences Conference*, Napier, New Zealand, 27-30 November 2018.

Ulayottil Venugopal, A., **Bertler**, N.A.N., Lee, J.E., Cortese, G., Pyne, R.L. (2018). Insights into phasing and evolution of the ocean bipolar see-saw from the RICE Ice Core. *American Geophysical Union*, Washington D.C., USA, 10-14 December 2018.

Vargo, L., **Horgan**, H., **Anderson**, B., **Mackintosh**, A., Lorrey, A. (2018). Investigating the drivers of change for New Zealand's glaciers using historic photogrammetry and finite element modelling. *International Glaciological Society Symposium*, Buffalo, New York, 3-8 June 2018.

OUR PEOPLE

Andrew Mackintosh
Director & Professor
Glaciology & modelling

Alex Pyne
SDO Director & Projects Manager

Brian Anderson
Senior Research Fellow
Glacial modelling

Peter Barrett
Emeritus Professor
Stratigraphy & Antarctic climate history

Nancy Bertler
Associate Professor
Ice core climatology

Lionel Carter
Professor
Ocean history & processes

Ruzica Dadic
Senior Research Fellow
Snow & ice processes

Warren Dickinson
Senior Research Fellow
Sedimentary petrology

Michelle Dow
Centre Manager

Gavin Dunbar
Senior Lecturer
Sedimentary geology & geochemistry

Bella Duncan
Postdoctoral Fellow
Paleoceanography

Shaun Eaves
Lecturer
New Zealand Glaciology

Nick Golledge
Associate Professor
Ice sheet modelling

Huw Horgan
Senior Lecturer
Glacial geophysics

Stefan Jendersie
Research Fellow
Ocean Modelling

Richard Levy
Associate Professor
Stratigraphy

Darcy Mandeno
Science Drilling Office
Operations and Field Engineer

Rob McKay
Associate Professor
Stratigraphy & sedimentology

Tim Naish
Professor
Sedimentology & paleoclimatology

Dao Polsiri
Administrator &
NZ SeaRise Project Manager

ARC ADVISORY BOARD

Dave Harper (Convenor), Pro Vice-Chancellor, Victoria University
Peter Smith, Antarctica New Zealand
Craig Cary, New Zealand Antarctic Research Institute
Amy Laurenson, Ministry of Foreign Affairs & Trade
Ian McIntosh, Research Office, Victoria University
Rob Murdoch, NIWA
Ian Simpson, GNS Science
John Townend, SGEES, Victoria University
Prue Williams, Ministry of Business, Innovation & Employment

ARC ADJUNCTS

Helen Bostock
Robert DeConto
Robert Dunbar
Peter Webb
Mike Williams
Dave Lowe
Terry Wilson
Dan Zwartz

GRADUATE STUDENTS

Hannah Chorley	PhD	Antarctic climatology
Lukas Eling	PhD	Paleoclimatology
William Gonzalez	PhD	Palynology
Georgia Grant*	PhD	Sedimentology
Benji Griffin	PhD	Sedimentology
Florence Isaacs	PhD	Antarctic climatology
Katelyn Johnson	PhD	Ice core climatology
Wei Ji Leong	PhD	Machine learning
Dan Lowry	PhD	Modelling
Jamey Stutz	PhD	Glaciology
Abhijith Ulayottil Venugoapl	PhD	Paleoclimatology
Laurine van Haastrecht	PhD	Antarctic glaciology
Lauren Vargo	PhD	Climate dynamics
Marjolaine Verret	PhD	Permafrost geochemistry
Arran Whiteford	PhD	Subglacial hydrology
Ross Whitmore	PhD	Glaciology

Lisa Dowling	MSc	Glaciology
Melanie Liston*	MSc	Paleoceanography
Karsten Lorentz*	MSc	Glaciology
Clarrie Macklin	MSc	Subglacial hydrology
Rebecca Pretty	MSc	Sedimentology
Simon Reeve	MSc	Paleoclimatology
Nikita Turton	MSc	Sedimentology

*thesis submitted in 2018

ASSOCIATED RESEARCHERS

Cliff Atkins	Senior Lecturer in Earth Sciences	Sedimentary processes and environments
Michael Hannah	Associate Professor in Earth Sciences	Marine palynology
Kevin Norton	Associate Professor in Geography	Geomorphology and geochemistry
Rebecca Priestley	Associate Professor - Science in Context	Antarctic science history
James Renwick	Professor in Physical Geography	Atmospheric circulation
Tim Stern	Professor in Geophysics	Solid earth geophysics and Transantarctic Mts

OTHER VUW ACADEMICS WITH ANTARCTIC INTERESTS

David Frame	Professor of Climate Change	Climate policy and future climate change
Margaret Harper	Adjunct Research Associate in Geology	Freshwater algae
Malcolm Ingham	Senior Lecturer in Physics	Properties of sea ice
Mark McGuinness	Professor in Mathematics	Modelling
Joanna Mossop	Associate Professor in Law	International law
Nigel Roberts	Emeritus Professor of Political Science	Antarctic politics and history
Ken Ryan	Associate Professor in Antarctic Biology	Marine algae
Rhian Salmon	Senior Lecturer - Science in Context	Science communication
Ross Stevens	Senior Lecturer in Industrial Design	Design of remote field camps
Joe Trodahl	Emeritus Professor in Physics	Temperature conduction in ice and rock

LIST OF COLLABORATORS

National collaborators

Antarctica New Zealand
Aqualinc Research Ltd.
Bodeker Scientific Ltd.
GNS Science
HPFS Solutions
Massey University
Max Tarr Electrical Ltd.
Meridian Energy - Twizel
NIWA
University of Auckland
University of Canterbury
University of Otago
University of Waikato
Webster Drilling and Exploration Ltd.

International collaborators

Alfred Wegener Institute (Germany)
Binghamton University - State University of New York (USA)
British Antarctic Survey (UK)
Australian Maritime College
Cambridge University (UK)
Centre for Remote Sensing of Ice Sheets (USA)
Imperial College London (UK)
Chinese Academy of Meteorological Sciences
Chinese Academy of Sciences
Curtin University (Australia)
Dartmouth College (USA)
Durham University (UK)
ETH (Switzerland)
Hokkaido University (Japan)
Indiana State University (USA)
International Cable Protection Committee (UK)
Instituto Andaluz de Ciencias de la Tierra (Spain)
Istituto Nazionale di Geofisica e Vulcanologia (Italy)
Imperial College London (UK)
Istituto Nazionale di Oceanografia e di Geofisica Sperimentale (Italy)
Japan National Institute for Polar Research (Japan)
Jilin University (China)
Korean Polar Research Institute (Republic of Korea)
Laboratoire de glaciologie et géophysique de l'environnement (France)
Lamont-Doherty Earth Observatory (USA)
Lawrence Livermore National Laboratory (USA)
Los Alamos National Laboratory (USA)
Macquarie University (Australia)
NIOZ Royal Netherlands Institute for Sea Research (The Netherlands)
NOAA (USA)
National Oceanography Centre (UK)
National Sun Yat-sen University (Taiwan)
Niels Bohr Institute (Denmark)
North Dakota State University (USA)
Northern Arizona University (USA)
Northern Illinois University (USA)
Oregon State University (USA)
Scripps Institution of Oceanography (USA)
Southampton University (UK)
St. Olaf College (USA)
State University of New York (USA)
Swiss Federal Research Institute WSL (Switzerland)
Royal Holloway, University of London (UK)
The Australian National University
The Ohio State University (USA)
The Pennsylvania State University (USA)
University of Alaska, Fairbanks (USA)
University of Birmingham (UK)
University of California, Irvine (USA)
University of California, Davis (USA)
University of Colorado (USA)
University of Copenhagen (Denmark)
University of Delaware (USA)
University of Delhi (India)
University of Granada (Spain)
University of Lausanne (Switzerland)
University of Maine (USA)
University of Massachusetts (USA)
University of Milano-Bicocca (Italy)
University of Nebraska-Lincoln (USA)
University of New South Wales (Australia)
University of Stockholm (Sweden)
University of Tasmania (Australia)
University of Urbino (Italy)
University of Washington (USA)
University of Wisconsin-Madison (USA)
U.S. Geological Survey
Utrecht University (The Netherlands)
Virginia Institute of Marine Sciences (USA)
Worcester State University (USA)
Yale University (USA)

Antarctic Research Centre Annual Review 2018
Designed and edited by Michelle Dow

Contributions from:
Brian Anderson, Peter Barrett, Nancy Bertler, Lionel Carter, Michelle Dow, Gavin Dunbar, Shaun Eaves, Nick Golledge, Huw Horgan, Florence Isaacs, Andrew Johnson, Andrew Mackintosh, Rob McKay, Leo Pure, Alex Pyne, and Tim Naish.

Antarctic Research Centre
Te Pūtahi Rangahau i te Kōpakatanga ki te Tonga
Victoria University of Wellington
PO Box 600, Wellington 6140, New Zealand

www.victoria.ac.nz/antarctic | Antarctic-Research@vuw.ac.nz | +64-4-463 6587