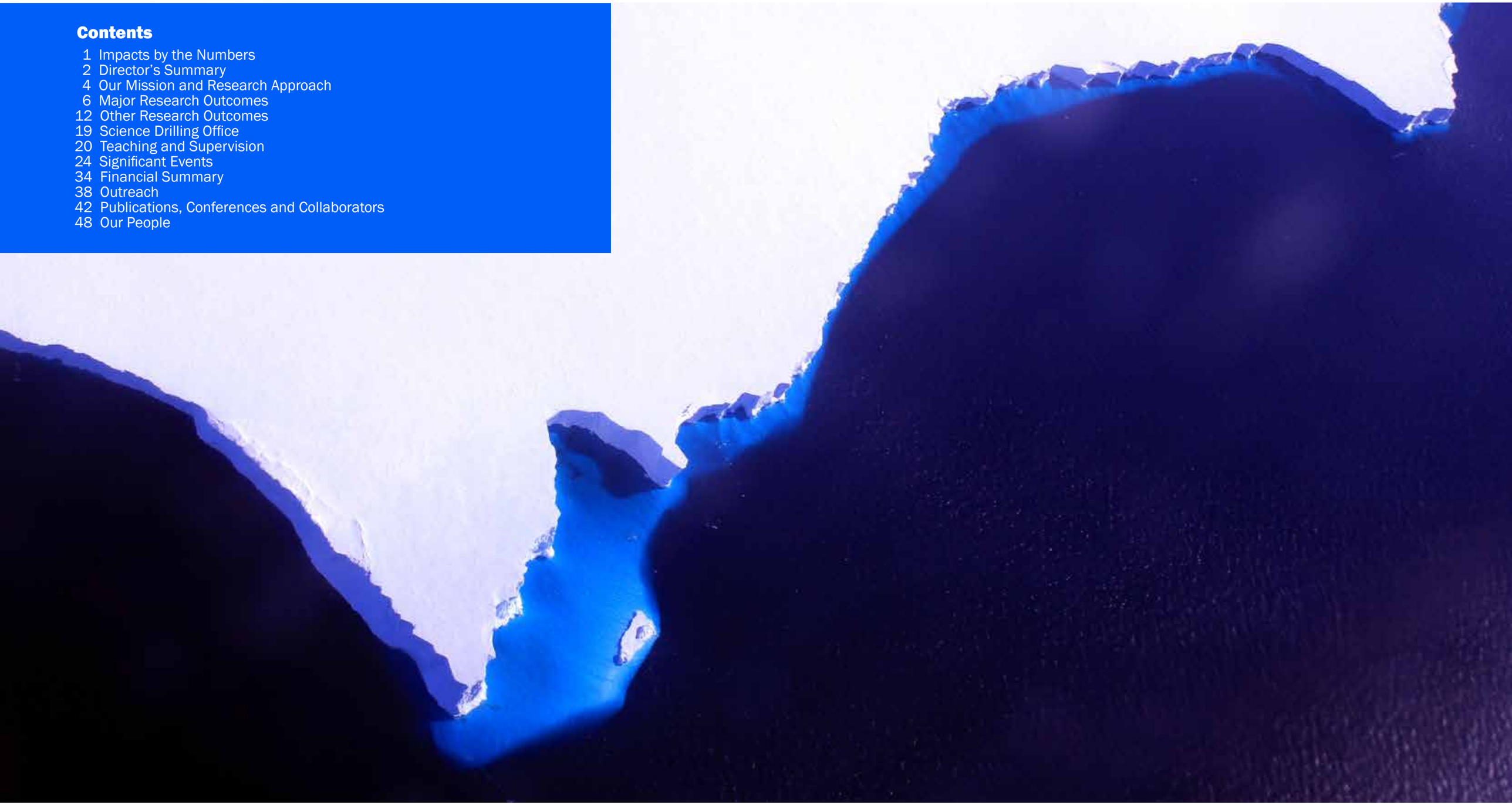
# ANTARCTIC RESEARCH CENTRE

## Annual Review 2017

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

## Contents





This Photo: Drygalski Tongue, Antarctica - Jamey Stutz
Cover Photo: Evan's Heights, Antarctica - Andrew Mackintosh

# OUR 2017 IMPACTS BY THE NUMBERS

## McKay Hammer

**the premier award of the New Zealand Geological Society** was won by Nick Golledge for his publications including a *Nature* paper which shows that climate change mitigation might save the West Antarctic Ice Sheet.

## 20 New Zealand scientists and students

attended the Past Antarctic Ice Sheet Dynamics (PAIS) Conference in Trieste, Italy co-organised by the ARC's Tim Naish. PAIS is a scientific research programme of the Scientific Committee on Antarctic Research (SCAR).

## 25 years

of New Zealand anomalous glacier advances explained for the first time in a *Nature Communications* paper by Brian Anderson, Andrew Mackintosh and others.

## ARC the 1st carbon neutral institute

at Victoria University through certified rainforest protection projects.

## UN officials

and government ministers have received Lionel Carter's co-authored book that presents a synopsis of legal and environmental aspects of submarine telecommunications cables on the High Seas.

## $960 thousand dollar Marsden Fund

awarded to Andrew Mackintosh to understand the effects of rapid climate change on New Zealand in the recent geological past. The team also includes ARC's Shaun Eaves and Lionel Carter.

## 250 scientists from 25 countries

came to our vibrant capital city campus to attend the International Symposium on the Cryosphere in a Changing Climate, hosted by Andrew Mackintosh and Victoria University.

## $7.1 million dollars

awarded to Tim Naish and an international team from the MBIE Endeavour fund to understand the impact of sea-level rise on New Zealand. The ARC team also includes Nick Golledge, Nancy Bertler, Andrew Mackintosh, and Brian Anderson.

## 403.3 parts per million

is the new record level of global atmospheric carbon dioxide concentrations from anthropogenic greenhouse gas emissions according to a new 2017 WMO Greenhouse Gas Bulletin by Nancy Bertler and colleagues.

## 29 media interviews

given by ARC staff on Antarctic and climate related issues.

## 43 presentations

given to schools, the public, stakeholders and decision makers by ARC staff.

## 2nd ARC IPCC Lead Author

Andrew Mackintosh was selected for the Special Report on the "Oceans and Cryosphere in a Changing Climate". He joins Tim Naish, lead author on the previous assessment. He will also be joined by Nick Golledge who has recently been selected in 2018.

## 370 metres drilled

through the Ross Ice Shelf in the 2017/18 season using the Hot Water Drill built by our Science Drilling Office duo Alex Pyne and Darcy Mandeno.

## $389K Deep South

**National Science Challenge** funding to better understand the effects of melting snow and ice on New Zealand. The ARC team includes Andrew Mackintosh, Ruzica Dadic, Brian Anderson, and Huw Horgan.

## 31 publications

by ARC researchers, including four in the *Nature* group.

## 8 theses submitted

by ARC supervised students - one PhD and seven MSc students.

Icons from www.flaticon.com

# DIRECTOR'S SUMMARY

Hughes Bluff, Antarctica
Photo: Andrew Mackintosh

The Antarctic Research Centre (ARC) is one of the most visible and influential centres of excellence at Victoria University of Wellington. Supporting the high-profile Antarctic science that we are renowned for has always been challenging. It requires creativity, international coordination and perseverance – and this year we have succeeded in attracting more than eight million dollars of new funding. We are proud of our reputation, which has developed over more than forty years, and continues to grow. In 2017 we published 31 papers in outstanding international journals, including four publications in the *Nature* group. Our academic staff have received awards, and prestigious international appointments, while our Science Drilling Office made a major technical breakthrough by drilling through the Ross Ice Shelf. And we have made progress in meeting international climate obligations by going carbon neutral. I am delighted to write about our successes here, following my first year as ARC Director.

Of special note in 2017 is the funding success of Tim Naish and an ARC team including Nick Golledge, Brian Anderson, Nancy Bertler and myself, who secured a 7-million-dollar project from the MBIE Endeavour Fund to provide improved sea-level rise projections for New Zealand, to better anticipate and manage impacts. This project involves many researchers from across New Zealand, including Victoria University, GNS Science, NIWA, the University of Otago, Auckland University, and a large team of international experts. It also includes representatives from regional councils, so that scientists have the most relevant information about infrastructure near sea level, and science is fed into policy.

In addition to Tim's success, a team led by myself, Shaun Eaves and Brian Anderson and including scientists from the United States, Denmark, Australia and Chile were awarded an almost million-dollar Marsden grant to study the Antarctic Cold Reversal, a period of abrupt global climate change that helps inform future ice sheet-climate interactions. Additionally, a team led by myself and Nicolas Cullen from Otago University received $389K in funding from the Deep South National Science Challenge to make future projections of Southern Alps snow and ice, and to determine their impact on water resources. This is the first time that the New Zealand community has received umbrella funding to support this societally-relevant work, and our team includes Ruzica Dadic, Brian Anderson and Huw Horgan from the ARC, and scientists from the Universities of Otago, Canterbury, NIWA, Bodeker Scientific Ltd., and Aqualinc Research Ltd.

Staff in our Centre have a common goal – to understand the impact of climate change on Antarctica and New Zealand, and to engage with society. Even though we are broad in our approach and background, we are united in purpose, and our Centre is a harmonious and intellectually vibrant environment, something that our international visitors always take notice of. We all contribute to the success of our Centre but each year there are stand outs. In 2017, Nick Golledge won the Alexander McKay Hammer – the premier award of Geosciences New Zealand for his contribution to Antarctic ice sheet modelling. And I have had the privilege of serving as a Lead Author on the Intergovernmental Panel on Climate Change (IPCC) Special Report on Oceans and Cryosphere in a Changing Climate.

We answer the most important and urgent science questions by being innovative. Our team is increasingly using physics and computer modelling to extend beyond our background and strength in paleoclimate studies. This allows us to also look forward as well as back, enhancing our ability to understand the climate system. We are now internationally recognised in a number of fields including ice-climate physics (Ruzica Dadic), ice-core climatology (Nancy Bertler), numerical modelling of ice sheets (Nick Golledge), modelling and monitoring of glaciers (Brian Anderson), glacier geophysics (Huw Horgan), glacier and ice sheet chronologies (Shaun Eaves), paleoceanography and marine cables (Lionel Carter), as well as the sedimentology and geochemistry that is our backbone (Bella Duncan, Warren Dickinson, Gavin Dunbar, Rob McKay and Tim Naish). The innovation and productivity of our academic staff would not be possible without the outstanding support provided by our Centre Manager Michelle Dow, and lately, by our new administrator Dao Polsiri.

Our Science Drilling Office led by Alex Pyne along with Darcy Mandeno are internationally recognised for their innovation. In 2017, as part of the NZARI-funded research programme led by Christina Hulbe at University of Otago, they developed a new hot water drilling system and used it to penetrate through 370 metres of the Ross Ice Shelf. With the support of Antarctica New Zealand, this allowed a group of scientists from multiple institutions to explore the ocean cavity beneath the ice shelf. Gavin Dunbar from the ARC used this opportunity to sample sediment from the ocean floor, which will reveal new information about the history of the Antarctic ice sheet and its sensitivity to climate change. 'The Long Haul' by Neil Silverwood, a beautifully-photographed article about this work, was recently published in *New Zealand Geographic*.

Our senior staff carry out significant engagement, communication and coordination with our national and international stakeholders. Tim Naish led the Past Antarctic Ice Sheet Dynamics (PAIS) Conference in Trieste, Italy, along with long-term ARC collaborator and SCAR/PAIS co-chair Laura De Santis. I led the International Conference on the Cryosphere in a Changing Climate in Wellington, with colleagues from the International Glaciological Society, International Association of Cryospheric Sciences, and the World Climate Research Programme Climate and Cryosphere project, and an organising committee of ARC and New Zealand-based scientists. This conference attracted more than 250 scientists from 25 countries to our capital city university. Lionel Carter gave four keynote talks on oceanography and marine cables in 2017, while Peter Barrett chaired his final meeting of the award committee for the Tinker-Muse Prize for Science and Policy in Antarctica. Increasingly our mid-career researchers are also leading in international science coordination and engagement – in 2017, Nancy Bertler co-chaired the 'Great Antarctic Climate Hack' workshop at Scripps Institute for Oceanography in San Diego, while our newest Associate Professor, Rob McKay, chaired the Australasian International Ocean Discovery Programme (IODP) Regional Planning Workshop in Sydney, Australia.

I am proud of our students, who each year complete their doctoral and master's degrees, and move on to excellent research jobs, while generating world-class publications, giving outstanding conference talks, and attracting funding of their own. This year Bella Duncan completed her PhD on fossil biomarkers and past Antarctic climates, and she is now working as a postdoctoral fellow in our Centre. Dan Lowry won the 2017 Antarctica New Zealand Sir Robin Irvine Postgraduate Scholarship for his ice sheet modelling work. Our students gave seven presentations at the International Symposium on the Cryosphere in a Changing Climate, and six presentations at the PAIS Conference. A highlight for me was hearing about PhD student Georgia Grant's outstanding presentation at the Regional Sea Level Changes and Coastal Impacts Conference in New York City. Georgia discussed her work on past sea levels during the Pliocene, a period of relevance to future climate, when air temperatures were only slightly warmer than today and sea level was significantly higher.

2018 has already started in a very exciting manner. We are beginning to engage with our new government with the goal of helping New Zealand to build a society that is more resilient to climate change. To that effect, we are working closely with Antarctica New Zealand and MBIE to help shape the new Antarctic science platform, which may support and guide Antarctic research for a decade or more. In February, Rob McKay, returned from the Ross Sea, where he was co-chief scientist of IODP Expedition 374, the first coring mission in this region in more than 40 years. In March, Nick Golledge was selected as an IPCC Lead Author, one of five scientists from Victoria to join the Sixth Assessment Cycle – a remarkable recognition of the quality of climate science at our university. I look forward to telling these stories and more in our 2018 Annual Review.

Professor Andrew Mackintosh
Director, Antarctic Research Centre

# OUR MISSION & RESEARCH APPROACH

## Improve understanding of Antarctic climate and ice sheet processes, their impact on New Zealand and the Earth system

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

Sea ice near Barne Glacier, Antarctica
Photo: Cliff Atkins

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 and facilities. It also contributes to both undergraduate and graduate teaching and supervision in the fields of climatology, sedimentology, glaciology, paleoclimatology and Antarctic affairs.

## Rationale

We are rapidly heading towards a climate that is 2-4 degC 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 recently 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.

# MAJOR RESEARCH OUTCOMES

Significant research enhancing our knowledge of the consequences of climate change

Hot Water Drill, Antarctica
Photo: Jane Chewings

# IMPROVED, LOCATION SPECIFIC, SEA-LEVEL RISE PREDICTIONS ARE ON THEIR WAY

A 5 year, $7.1M research programme funded by the MBIE Endeavour fund to improve sea-level rise predictions for New Zealand.

The collaborative NZ SeaRise Programme will be led by the ARC's Tim Naish in partnership with NIWA and GNS Science researchers, and world-leading international collaborators. The science leaders are Nick Golledge (ARC), Rob Bell (NIWA) and Richard Levy (GNS), while the ARC team also includes Brian Anderson, Nancy Bertler and Andrew Mackintosh.

The motivation for the programme was highlighted by the Parliamentary Commissioner for the Environment who stated in a recent report,

"It is certain that the sea is rising and will continue to do so for centuries to come. But much is uncertain – how rapidly it will rise, how different coastal areas will be affected, and how we should prepare."

To address this need, the NZ SeaRise Programme will produce new estimates of the magnitude and rate of sea-level rise for our coastal regions to 2100 and beyond. We will use these projections to examine environmental impacts and risks associated with increased coastal flooding due to storm surge and rising groundwater levels and incursion of salt water into coastal aquifers, estuaries, and wetlands. Our programme will improve global- and regional-scale sea-level projections, which currently underestimate the amount of future sea-level rise because they do not include accurate estimates of the contribution from melt of ice sheets in Antarctica and Greenland. With our expertise in modelling future polar ice sheet melt, and capability at NIWA and GNS Science, in estimating changes due to local sea surface height variations and vertical land movements, respectively, our team is uniquely positioned to take on this challenge. We will then establish local sea-level projections that include the effect of land movement. This is important as ground subsidence may cause local sea level to rise by an additional 20 to 30 cm by the end of the century. Finally, we will assess the environmental impact of the new sea-level rise projections in Wellington, Dunedin, Auckland, Hawkes Bay, and New Zealand's Scott Base in Antarctica. These impact studies will be co-designed with stakeholders. Outcomes will include improved decision making, risk management, and adaptation planning based on locally relevant sea-level rise scenarios and vulnerability assessments.

The programme complements and contributes to the aims of both the Deep South and Resilience National Science Challenges, and will provide an application of national benefit for Antarctic ice sheet research to be conducted under the new Antarctic research platform.

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# NEW ZEALAND GLACIERS CRITICAL FOR WATER RESOURCES AND TOURISM

Glaciers have always been of scientific interest as a dynamic and climate sensitive part of the landscape - but we are now starting to realise how important they are for economic reasons too.

Glaciers and snow are an important part of our mountain landscapes from an aesthetic and recreational perspective, but also have a large economic impact, through winter sports, tourism, water resources and hydroelectric power production. For example, the spectacular 1.5 km advance of Franz Josef and Fox glaciers from 1983 to 2008, and subsequent rapid retreat, had a fundamental impact on glacier guiding, with guided tours on foot being replaced with helicopter-only access since 2012. The cause of this spectacular and globally-anomalous advance was obscure - in a warming world, why did glaciers advance?

Our 2017 publication in *Nature Communications* lead by Andrew Mackintosh and Brian Anderson (ARC) and Andrew Lorrey (NIWA) answered this question by using mathematical modelling to show that most of the advance was due to lower temperatures during two discrete periods in the 1980 and 1990s. The positive mass balances that lead to the advance were closely linked to Tasman Sea surface temperatures.

However, these two glaciers do not tell the whole story of glacier change in the Southern Alps. There are a wide range of different glaciers, with contrasting processes of ice flow and mass loss. Oblique aerial photos taken of a subset of New Zealand glaciers since 1977 by Trevor Chinn and colleagues contain a treasure trove of information which has only partly been explored. In collaboration with NIWA and supported by Andrew Lorrey's project 'Climate Present and Past', we are now making the most of this archive. PhD student Lauren Vargo has been using these historic photos to quantitatively reconstruct glacier changes in the Southern Alps over the last four decades. She initially focussed on Brewster Glacier, near Haast Pass, and showed that while Fox and Franz Josef glaciers did their remarkable advance, Brewster Glacier did very little - it paused its retreat, and advanced just a few metres. Length changes only tell part of the story, and Merijn Thornton's Masters thesis showed that the glacier did gain mass during this period. Haupapa/Tasman Glacier is the largest in New Zealand, and understanding its dynamics and calving processes are critical to understanding the future of New Zealand's glaciers. Ed Lui, in his Masters thesis, used time-lapse photography of Tasman Glacier to quantify, for the first time, the amount of ice loss at the terminus from large calving events, and make a start in understanding rates and processes of terminus retreat. Sam Taylor-Offord, in his Masters thesis, explored the relationship between movement of the glacier and the seismic signals it generates, showing how waves of faster-moving ice move down the glacier. The implications of the contrasting processes and responses of these glaciers will be further explored by reconstructing changes of many more New Zealand glaciers from the historic aerial photography set, and combining it with dynamic glacier modelling to elucidate the patterns of climate change in the Southern Alps over recent decades, and the details of their dynamic response.

During 2017 we have seen extreme weather conditions across New Zealand with a December drought coinciding with a 'marine heat wave' where Tasman Sea temperatures have been as much as 6 degC warmer than usual. The below-average winter snowpack melted quickly and left only glacier melt to support summer flows in many alpine streams. As a result, southern hydro lake levels are low, because of the combination of low rainfall and limited snowpack. This is an example of the kind of weather patterns that we expect the see in the future, where warmer temperatures lead to shallow snowpacks which melt long before peak demand for irrigation and hydropower, and glaciers lose mass at a rapid rate. Long term, we expect that water availability in mid to late summer will decrease as glaciers shrink and can no long supply melt water. Quantifying these changes, in ways that are useful for stakeholders, is part of the Deep South National Science Challenge - Our Frozen Water Resources. We have developed snow and glacier models which are being applied and tested against satellite images of seasonal snow and long-term glacier change, with our partners at NIWA, University of Otago, University of Canterbury, Bodecker Scientific Ltd., and Aqualinc Research Ltd. Ultimately we aim to make projections of the change in glaciers, snow pack, and water runoff which will be important for New Zealand's economic future.

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Brewster Glacier, New Zealand
Photo: Alice Doughty

# ICE SHEET INTERACTION WITH THE GLOBAL CLIMATE SYSTEM

As global sea level continues to rise at an accelerating rate, our ice-sheet modelling research focuses more and more on better understanding how the Antarctic and Greenland ice sheets are contributing to this rise, and how they might respond to future environmental changes.

Over recent years our ice-sheet modelling research in the ARC has expanded significantly, swelled by new PhD students and numerous overseas collaborations, and underpinned largely by funding from the Royal Society Te Apārangi, the Ministry for Business, Innovation and Employment (MBIE), and many other sources.

Whilst the West Antarctic Ice Sheet is known to be the most vulnerable to a warming climate, due to it's bed lying up to two kilometers below present sea level, it is the East Antarctic Ice Sheet that holds the greatest volume of ice - about 53 m of sea-level equivalent water, ten times that of West Antarctica. In the ARC, much of our fieldwork and modelling research has sought to investigate this larger ice mass, and to quantify how it changed during past climate transitions. This approach of combining fieldwork and computer modelling to tackle a single question is immensely powerful, and the use of the two methods together allows us to make robust predictions for the future.

In 2017, ARC researchers published a range of new Antarctic ice sheet model simulations that each investigated a different question. One of these studies, led by Pepijn Bakker at MARUM, Germany (Bakker *et al.*, 2017) and utilising simulations performed by the ARC's Nick Golledge, looked at global climate variability through the Holocene - the period of geological time that spans the relatively warm conditions that we have experienced for the last approximately 10,000 years following the end of the last ice age. The problem that Bakker and his team were trying to solve was, why do global climate models nearly always underestimate the amount of natural variability in the climate system? This is an important problem, because it is precisely these models that are used to make predictions about future climate changes and which in turn are used to guide government policy. Bakker thought that perhaps the answer lay in Antarctica, and in particular, in the effects that meltwater released from the ice sheet might have on the temperature and salinity of the surrounding Southern Ocean. By using the ice sheet model to quantify these meltwater fluxes and their variability over thousands of years, Nick provided the necessary inputs required to test this idea. The results, published in the leading scientific journal *Nature*, were remarkable, and confirmed Bakker's earlier hunch. What was found was that even very small amounts of meltwater, discharged into the ocean, were sufficient to change the way that the ocean mixes and transports heat. The knock-on effect is that these changes in oceanic heat transfer in turn influence the temperature of the overlying air masses. The simulations also illustrated a previously-known 'seesaw' effect, in which the release of meltwater in Antarctica leads to cooling of the surface water around the ice sheet, and a cooling of air temperatures across the Southern Hemisphere, but a warming of surface temperatures in the Northern Hemisphere. This study therefore not only explained the climate variability problem that was the original goal, but also led to new insights into how future meltwater from Antarctica might affect global climate over coming decades to centuries.

In a separate study published in *Geophysical Research Letters* (Golledge *et al.*, 2017), Nick used his ice sheet model to investigate the differing roles played by atmosphere, ocean, and bedrock topography in controlling the long-term evolution of the Antarctic ice sheets. Using a range of simplified climate states that represented different scenarios of atmospheric and oceanic warming, he ran simulations for the whole continent and analysed the results on a catchment-by-catchment basis. What was immediately striking was that different sectors of the West and East Antarctic ice sheets respond in very different ways, and perhaps more importantly, they each respond preferentially to different drivers. The simulations showed, as expected, that West Antarctic drainage basins were most sensitive to ocean warming, but what was less expected was that whilst the majority of East Antarctica is sensitive mainly to a warming atmosphere, there are one or two catchments that are uniquely sensitive to the ocean. Of these, the Recovery Basin catchment, in the eastern Weddell Sea, appeared to be the most sensitive, and in fact behaved in many ways like a West Antarctic system. The significance of this finding is that the Recovery Basin is currently an area that has received very little attention, being remote and difficult to access. But observational and modelling data are increasingly beginning to show that climate-driven changes are occurring in this area, and that these changes may lead to significant retreat of part of the ice sheet there. By contrast, sectors such as the Totten Glacier have attracted more attention over recent years because measured ocean warming there is considered to pose a threat to the stability of what is a large and important glacier. But this new analysis suggests that the Totten Glacier sector of the ice sheet is buffered from ocean-driven retreat by the topographic configuration of its bed. Essentially, the glacier rests on a complex landscape of hills and valleys, rather than a single deep basin, so any retreat of the glacier in this area will be relatively slow.

Together, these and other studies are revealing more and more about the complexity of ice sheet behaviour and how ice sheets interact with the global climate system. By continually refining these computer models, and gathering the field data to calibrate them, the ARC is contributing to an increasing global effort to better predict the future of our global ice sheets.

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# HOT WATER DRILLING INTO THE WORLD'S LEAST KNOWN OCEAN

Over the last two years the ARC, Antarctica New Zealand, and our New Zealand Antarctic Research Institute (NZARI) partners have embarked on an ambitious programme directly accessing the ocean cavity beneath the Ross Ice Shelf.

The Ross Ice Shelf is almost twice the size of New Zealand, but prior to this year direct observations of the ocean and seafloor underneath it were based on a single site drilled in the late 1970s, and a site near the grounded ice streams drilled in early 2013. Despite this paucity of observations, the ice shelf is thought to play a key role in 'holding back' or buttressing the ice presently flowing from the East and West Antarctic ice sheets. If this buttressing effect was removed due to loss of the ice shelf, the flow of ice from the ice sheets is anticipated to increase dramatically, raising sea level, changing local ecosystems, and most likely changing global ocean and atmospheric circulation.

This year the NZARI-funded multi-institutional Ross Ice Shelf Project made a major contribution to our understanding of the ice shelf, doubling the number of holes in the interior of the ice shelf, and hugely increasing the quantity of direct observations from beneath the ice shelf. The drilling season resulted from New Zealand's largest Antarctic traverse since the 1957 Hillary expedition to the South Pole, shifting tonnes of equipment and fuel to the hot water drilling site (prosaically named HWD-2), 350 km south east of Scott Base. The camp comprised polar tents of a type that both Hillary and Scott would have recognised along with state-of-the-art hot water drilling and scientific equipment.

Two holes were melted through the ~370 m thick ice allowing access to the ocean cavity, and sea floor a further 410 m below the base of the ice. The first hole was used for long term moorings which will return data over a number of years. Instruments for measuring ocean temperature, salinity and current speed were deployed by NIWA and a series of seismographs for measuring ice shelf properties were deployed by Auckland and Otago universities. The second hole was used for recovering sediment cores, further oceanography and microbiology. The team which included Gavin Dunbar and Georgia Grant (ARC), Christian Ohneiser (University of Otago) and Jeff Dunne (Antarctica New Zealand) collected 11 sediment cores, up to 65 cm long before the corer hit a very hard gravel layer, probably deposited during the last ice age and compressed by the weight of overlying ice. The tools used to melt the hole through the ice proved surprisingly adept at collecting sediment that melted out of the ice shelf, the portions of which proved surprisingly debris rich. The combination of sea floor and ice shelf sediment will enable us to reconstruct the retreat history of the ice shelf since the last ice age and provide insight into flow patterns of the ice shelf since then.

Now the ARC, Antarctica New Zealand, and our NZARI partners are preparing for the second phase of the Ross Ice Shelf Project. This will see hot water drilling and direct access at the mouth of Kamb Ice Stream. This ambitious project, which will require a 1200 km traverse and drilling through ~600 m of ice, will probe the past and future behaviour of the West Antarctic Ice Sheet directly at the source of the ice that will determine future sea level. Beginning in the 2019/2020 season we will be drilling into the ocean cavity near to the ice stream—ice shelf transition. This location, which was identified by surveying reported in *Geophysical Research Letters* (Horgan *et al.*, 2017), was beneath the ice stream as little as 150 years ago, and now exhibits a shallow (~30 m) ocean cavity. Central to our upcoming observations at this site are stratigraphic cores, which will record the past behavior of the ice sheet, and oceanic observations, which may well indicate the ice shelf's fate.

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# OTHER RESEARCH OUTCOMES

Tasman Lake, New Zealand
Photo: Huw Horgan

# PAST CLIMATE WINDOWS PROVIDE IMPROVED VIEW OF THE FUTURE

## Big milestone achievements for the international RICE team – RICE17.

The New Zealand-led Roosevelt Island Climate Evolution (RICE) project celebrated a number of major milestones in 2017. Most importantly, in a concerted, international and multidisciplinary effort, the RICE17 age scale was completed. The age scale comprises two merged parts, a seasonally resolved age scale for the past 2,700 years based on an annual layer count of the top 344 m of the RICE ice core and a deeper time age scale that spans the past 83,000 years (to a depth of 753 m) predominantly based on matching high resolution gas records. The annual layer count, an effort led by the University of Copenhagen, used continuous flow measurements of black carbon (University of Curtin), Ca, pH, and conductivity (University of Copenhagen), water stable isotope record (GNS Science) and discrete geochemical data (Victoria University, University of Maine, University of Curtin and the Chinese Cold and Arid Regions Environmental and Engineering Research Institute). The team achieved very low uncertainties with the past 100 years of ≤ ±2 years, for the past 1000 years ≤ ±19 years and for the past 2000 years ≤ ±38 years, reaching a maximum uncertainty of ±45 years at 344 m depth (Winstrup *et al.* in review). This age scale was extended back to 83,000 years with an effort led by Oregon State University using high resolution methane measurements (Oregon State University, University of Copenhagen), water isotope data (GNS Science), oxygen isotope of the air content along with ice flow modelling (University of Washington, Scripps Institution of Oceanography) and volcanic ashes (University of Maine). This age scale was developed by matching the RICE data with the superbly dated West Antarctic Ice Sheet Divide Ice Core (WDC) for the past 68,000 years and from 68,000 to 83,000 years with the high resolution North Greenland Ice Core Project (NGRIP). The RICE ice core was the second core to be analysed for continuous flow methane measurements after the WDC core which provided a unique opportunity to use the high resolution WDC and NGRIP age scales. The ice below 753 m is not yet dated but might contain ice from the last interglacial and beyond. For our newest publications and other news please see www.rice.aq.

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## Developing new drilling proposals in the Southern Indian and southwest Pacific oceans.

A workshop held at Sydney University, Australia from 13-16 June 2017 investigated future International Ocean Discovery Programme (IODP) drilling opportunities in the southwest Pacific Ocean, and the Southern Indian and Pacific sectors of the Southern Ocean and Antarctic margin. Rob McKay was the lead scientific convenor of the workshop, while Tim Naish chaired a breakout session to nurture new proposals focussed on climate-based themes. A total of 23 proposal ideas were discussed, with ~12 of these deemed mature enough for active proposal development. Of the remaining 11 proposals, key regions were identified where fundamental hypotheses are testable by drilling, but either site surveys are required or hypotheses need further development.


Rob McKay, Tim Naish, and Peter Barrett visit the IODP drilling vessel *Joides Resolution* whilst in port at Lyttleton Harbour

Two mature proposal ideas were discussed in the Totten Glacier region of East Antarctica, and eight more ideas were discussed for sites in the Southern Ocean. It is expected that this workshop will lead to a new phase of scientific ocean drilling in the Australasian region in the early 2020s, when the IODP drilling vessel *JOIDES Resolution* is due to return to these waters.

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## A new Victoria University/ GNS Science organic geochemistry facility.

Following on from completing her PhD in 2017, Bella Duncan started a postdoctoral fellowship in August to continue her work investigating what molecular fossils, known as biomarkers, can tell us about past climate in Antarctica and the Southern Ocean. A key component of this research has been to set up a facility to process and analyse for biomarkers in Wellington. Based at the National Isotope Centre, GNS Science, this facility is a joint effort between Bella and Rob McKay of the ARC, and Sebastian Naeher of GNS Science. The VUW/GNS Organic Geochemistry Laboratory is now up and running to extract organics from samples, separate out different compounds, and run analyses to identify and quantify the biomarkers present in samples. The development of this facility brings a new capability to Wellington, and means that we can now process for biomarkers and run a selection of analyses here, rather than sending samples overseas.

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Organic Geochemistry Laboratory, GNS Science
Photo: Sebastian Naeher

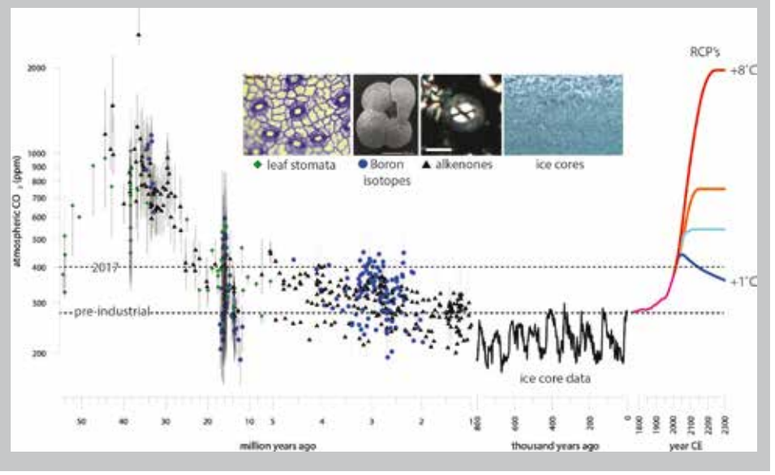
## WMO Greenhouse Gas Bulletin notes $CO_2$ emissions reach record high.

Nancy Bertler along with colleagues from GNS Science; Richard Levy and Jocelyn Turnbull, contributed a paleo-perspective to the 2017 WMO Greenhouse Gas Bulletin – State of the Greenhouse Gases in the Atmosphere Based on Global Observations. Ice core records reveal that over the last eight swings between glacials and interglacials atmospheric carbon dioxide ($CO_2$) varied between 180 and 280 parts per million (ppm). In comparison in 2016, anthropogenic greenhouse gas emissions raised atmospheric concentrations of $CO_2$ to a new record level of 403.3 ppm globally.

We have to look back 3-5 million years ago to find a time in Earth's history with similarly high $CO_2$ concentrations. Then, global mean surface temperatures were 2-3 degC warmer than today, the Greenland and West Antarctic ice sheets had vanished and even parts of the low lying basins of East Antarctic ice had retreated. This caused global sea level to be 10-20 metres higher than today. But how quickly did greenhouse gas concentrations change in the past? High resolution ice core records from high snow accumulation regions in West Antarctica along with a new generation of ice cores – horizontal ice cores where old ice lays close the surface – along with new analytical techniques provide exciting insights into how quickly atmospheric $CO_2$ concentrations can change.

Today's decadal rate of about 2.2 ppm per year is 20 times faster than the most abrupt natural increase observed. Travelling further back in time, using geological records of alkenones, fossil leave stomata and boron isotopes, we can observe examples of things to come. 15-17 million years ago, $CO_2$ concentrations were between 400-650 ppm, with global mean temperatures 3-4 degC higher than today and global sea level up to 40 metres higher during the warmest periods. With the world aiming to reduce greenhouse gas emissions in accord with the UNCCC Paris Agreement, these treasurable windows into the past caution us to double our efforts.

**CONTACT:** Nancy.Bertler@vuw.ac.nz




Reconstructions of $CO_2$ from proxy data: boron isotopes (blue circles), alkenones (black triangles) and leaf stomata (green diamonds). Direct measurements from Antarctic ice cores and modern instruments (pink). Future estimates include representative concentration pathways (RCPs) 8.5 (red), 6 (orange), 4.5 (light blue) and 2.6 (blue)

# FORCINGS AND FEEDBACKS; WHAT DRIVES GLACIERS AND ICE SHEETS?

## Patterns and timing of glacial retreat in the Ross Sea.

The southwest Ross Sea region has long been inferred to be the "keystone" for interpretation of the post Last Glacial Maximum retreat in the Ross Sea - on the basis of its inferred glacial flow pattern during the last phase of grounded ice. This led to a hypothesis that it was expansion of grounded ice in the central Ross Sea that acted to buttress and thicken East Antarctic Ice Sheet outlet glaciers, and retreat in the central Ross Sea embayment must have postdated retreat in the southwest Ross Sea. As such, coastal records of deglaciation along the Transantarctic Mountains have commonly been used to infer widespread retreat of ice sheets in the wider Ross Sea embayment.

A paper published in *Geology* (Lee *et al*., 2017), involving ARC researchers Rob McKay and Nick Golledge, directly tested this hypothesis using geophysical multibeam bathymetry data collected by the Korean Polar Research Institute. These data showed that thick (>700 m) and extensive East Antarctic Ice Sheet outlet glaciers flowed independently into the Ross Sea during the final phases of ice sheet grounding, and there was limited influence from "buttressing" ice sourced in the Central Ross Sea. Consequently, final retreat of these East Antarctic outlet glaciers may have significantly lagged the main phase of ice sheet retreat in the central Ross Sea.

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## The recent retreat of Kamb Ice Stream's grounding zone.

Grounding zones occur at the transition from an ice sheet to an ice shelf and can be thought of as the ice sheet's coastline. Along with delineating whether ice is still in the ice sheet, or contributing to global sea level, changes in the location of grounding zones have become a useful state-of-health indicator for ice sheets. Special attention is paid to the grounding zones of West Antarctica due to a long-standing instability hypothesis that predicts that grounding zone retreat on an inland-sloping bed is likely to be subject to a feedback, resulting in ongoing retreat. Grounding zones have been observed to retreat rapidly in parts of West Antarctica (e.g. Pine Island Glacier in the Amundsen Sea) but the grounding zones that fringe the Ross Ice Shelf have been considered relatively stable, based on inferences from remote sensing data. That is until now. Horgan *et al.*, (2017) have used geophysical and remote-sensing observations to demonstrate that the grounding zone of Kamb Ice Stream (KIS) has retreated at least 25 km within the last 150 years. KIS is one of the major ice streams that enter the Ross Ice Shelf. Perplexingly, KIS ceased to flow approximately 150 years ago, and Horgan *et al.* suggest that the observed retreat has likely resulted from the starvation of ice from upstream leading to a downstream thinning and floatation. This result makes planned Ross Ice Shelf Project hot water drilling into the ocean cavity at the KIS grounding zone even more exciting now that we know that the sea floor was recently the base of a fast flowing ice stream.

**CONTACT:** Huw.Horgan@vuw.ac.nz

Geophysical acquisition across the grounding zone of Kamb Ice Stream
Photo: Sam Taylor-Offord



## 'Reconstructing Climate from Glaciers' – unique *Annual Reviews* paper from decade-long collaboration with Raymond Pierrehumbert.

Back in 2007, Professor George Denton from the University of Maine introduced Andrew Mackintosh and Brian Anderson to Raymond Pierrehumbert, a renowned climate expert and then Louis Block Professor of Geophysical Sciences at the University of Chicago. In the decade since, Andrew, Brian and Ray have together investigated the detailed physics that drive glacier response to climate change. This collaboration has taken Ray to the summit of Tasman Glacier in New Zealand, and Andrew to the top of Sears Tower in Chicago. It has included working together on computer simulations powered by the sun at Brian's off-grid house on the West Coast of the South Island. More recently, Andrew finalised the work at Trinity College and the Department of Physics at the University of Oxford, where Ray is now Halley Professor of Physics. In 2017 we published an invited, 16,000 word, 30-page treatise called 'Reconstructing Climate from Glaciers' in the prestigious journal *Annual Reviews in Earth and Planetary Sciences* (impact factor > 10). This paper combined work from Andrew's career, including studies of glaciers in Iceland, Greenland and New Zealand, with Brian's expertise in numerical modelling, and Ray's remarkable understanding of the climate system. We hope that this paper becomes a standard reference on glacier response to climate for years to come.

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Raymond Pierrehumbert visiting Tasman Glacier in March, 2007
Photo: Andrew Mackintosh

## Abrupt climate change: Lessons from the past.

Between 18,000 and 11,000 years ago, atmospheric $CO_2$ increased by approximately 100 parts per million, global climate warmed by 4-5 degC, and large ice sheets began to melt – ultimately raising global sea level by ~120 metres. However this climate transition was not a smooth one, as feedbacks induced by increasing temperatures and melting ice resulted in several abrupt warming and cooling events that lasted a few hundred to a couple of thousand years. Deciphering the nature and causes of these previous non-linear climate events may help reduce the risk from future abrupt climate change.

Recently published papers reconstructed the response of mountain glaciers in both hemispheres to these abrupt climate events. In Scotland we examined the form and composition of sediments deposited at the margins of a former valley glacier, which provide a remarkably detailed record of multiple advance and retreat events during the last deglaciation (Jones *et al*., 2017). In the Southern Alps, we used glacier modelling to show that air temperatures in New Zealand may have been as much as 3 degC cooler than present during times of past abrupt cooling (Eaves *et al.*, 2017). We are currently using these results, along with many other climate-proxy datasets, to evaluate global climate model experiments designed to elucidate the ultimate cause of past abrupt climate change events in a warming world.

**CONTACT:** Shaun.Eaves@vuw.ac.nz

## How much glacier ice is there is the world? Surprisingly, we don't really know, but a new project is developing tools to find out.

Mountain glaciers and small ice caps are melting fast and they collectively hold a lot of ice - enough to raise sea-level by about 43 cm. Before the recent completion of the Randolph Glacier Inventory we didn't even know how many glaciers there are as they often exist in remote and uninhabited parts of the world. While each of the 215,547 glaciers have now been mapped and summarised, there is still a lot of uncertainty in how much ice they actually contain, largely because only 0.5% of these glaciers have any thickness measurements at all.

ITMIX, the Ice Thickness Models Intercomparison eXperiment, will reduce that uncertainty by providing a robust and spatially-explicit calculation of ice thickness for each glacier based on physical principles of mass balance and glacier flow. In the first phase, 17 existing models for ice thickness calculation were applied to 21 test glaciers, including two from New Zealand. The test was blind as the participants were not given measured ice thickness from these glaciers, but had to rely on their models to provide the answer. The result was that no single model is accurate at estimating ice thickness, and there are large deviations between individual solutions and even between solutions of the same model category. The local spread often exceeded the local ice thickness.

These results (Farinotti *et al*., 2017) highlight the importance of using ensemble results for ice thickness estimates, rather than relying on individual models, and also opens the door to robust global estimates of ice thickness, which is the goal of Phase Two of the project. These results will, in turn, feed into the glacier model intercomparison project (GlacierMIP) which will produce robust global estimates of sea-level rise from glacier melt.

**CONTACT:** Brian.Anderson@vuw.ac.nz

# EARTH AND OCEAN CONNECTIONS

## Fingerprinting granite erratics.

The Antarctic Dry Valleys are thought to have been ice-free for most of the last 14 million years. Beacon Valley, first mapped by VUW graduates McKelvey and Webb in 1958, has a complex history of glaciation. Most intriguing is the massive ice that underlies some of the glacial sediments in part of the valley. The origin of this ice is highly controversial because a volcanic ash dates it at about 8 million years old and most calculations show that it should have sublimated long before this. Small numbers of granite boulders and clasts are associated with this ice, yet there is no apparent source for these erratics.
Warren Dickinson along with a former student Gretchen Williams and other colleagues (Dickinson *et al*., 2017) analysed geochemical fingerprints (lead isotopes) of the granite erratics to determine their source. They showed that the granite erratics came from the Dry Valley Plutons, and tentatively from several specific plutons. This suggested that the erratics were emplaced in the mid-Miocene about 15 million years ago, long before the massive ice. Fingerprinting granite clasts in other high elevation locations in the Dry Valleys may help identify the flow paths of the mid-Miocene glaciers and lead to a better understanding of the paleoclimate at that time.

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Granite erratics on the surface of an old moraine in Beacon Valley, Antarctica
Photo: Warren Dickinson

## Science and politics – Action on the High Seas.

Legally, the term High Seas refers to the ocean beyond national jurisdiction. This is usually waters beyond the 200 nautical mile limit of the Exclusive Economic Zone (EEZ) off coastal and island states. Perusal of a global chart shows that most of the Southern Ocean is High Seas, bearing in mind that Antarctica has no formally recognised EEZ. Likewise, vast tracts of the other oceans are also classified as High Seas.

Concern over anthropogenic climate change and other effects of human activities, in particular the recovery of living and non-living marine resources, has been discussed at recent meetings at the United Nations and at other marine fora. UN discussions come under the banner of Biodiversity Beyond National Jurisdiction (BBNJ) with the New Zealand Ministry of Foreign Affairs and Trade playing a prominent role. Broadly speaking, a key aim is to strike a balance between wise, sustainable use of the oceans and marine protection and conservation.

One way to address this issue is to provide quality, peer-reviewed science to allow for informed decision making. The world is moving from the realm of expert opinion to an evidence-based approach regarding marine environmental matters. In that context, ARC member Lionel Carter has co-authored a book (Burnett and Carter, 2018) that presents a synopsis of legal and environmental aspects of submarine telecommunications cables on the High Seas. The book is based on publically available science papers and industry reports and is presented in a non-technical format to inform the widest possible audience. To date, it has been circulated to UN officials involved with the BBNJ negotiations as well as to relevant ministers of the New Zealand Government.

**CONTACT:** Lionel.Carter@vuw.ac.nz



# HOT WATER DRILLING ON THE ROSS ICE SHELF

## The Science Drilling Office provided critical support to the Ross Ice Shelf Project during this year's field season.

The Science Drilling Office (SDO) is hosted in the Antarctic Research Centre and led by Alex Pyne, SDO Director and ARC Projects Manager, along with Darcy Mandeno, Operations and Field Engineer.

The primary focus of the Science Drilling Office in 2017 has been the preparation and operation of our new hot water drilling system. We have built a modular Hot Water Drill based on experience and designs developed by the British Antarctic Survey.

At Windless Bight during the 2016/2017 Antarctic summer season, we were able to test the system and identify several issues that required improvement for the 2017/2018 season, planned for the HWD-2 site on the Ross Ice Shelf.

In addition to the full-time work on equipment and season planning by Darcy and Alex, we also employed Jeff Rawson for around eight weeks to work in Christchurch on our generator issues.

Our drilling team for the Antarctic season of 11 weeks consisted of Alex (team leader), Darcy (engineer/driller), Jeff (mechanic/driller), Hedley Berge (electrician/driller), Jane Chewings (Driller - seconded from SGEES).

We had a successful season of drilling at the HWD-2 site, completing two holes through the ~370 m thick ice shelf. The first hole was used to deploy a long term oceanographic mooring, and also to freeze in a seismic experiment. The second hole was kept open for 11 days, enabling multiple science experiments to be carried out in the ocean cavity and on the ocean floor beneath the ice shelf.

**CONTACT:** Alex.Pyne@vuw.ac.nz

Darcy Mandeno and Hedley Berge
Ross Ice Shelf Project, Antarctica
Photo: www.neilsilverwood.com

# TEACHING & SUPERVISION

David Glacier, Antarctica
Photo: Andrew Mackintosh

# TEACHING AND 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 2017 our staff supervised 16 PhD and 11 MSc students and contributed to the following courses:

## Undergraduate and graduate courses

| | |
|---|---|
| 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

## PhD and MSc completions

**Bella Duncan** (PhD)
"Cenozoic Antarctic climate evolution based on molecular and isotopic biomarker reconstructions from geological archives in the Ross Sea region"
- Supervised by Rob McKay and Tim Naish (ARC).

**Olya Albot** (MSc)
"Pleistocene cyclostratigraphy on the continental rise and abyssal plain of the western Ross Sea, Antarctica"
- Supervised by Rob McKay and Gavin Dunbar (ARC).

**Hannah Brightley** (MSc)
"A paleoclimate reconstruction of the Little Ice Age to modern era climate conditions in the Eastern Ross Sea, Antarctica as captured in the RICE ice core"
- Supervised by Nancy Bertler and Lionel Carter (ARC).

**Libby Galbraith** (MSc)
"Reconstructing Neogene climate and glacial history of Southern McMurdo Sound, Antarctica"
- Supervised by Tim Naish (ARC) and Richard Levy (GNS Science).

**Charles Maxson** (MSc)
"Carbon isotopic equilibrium of the surface waters as a proxy for climate change through the last glacial/interglacial cycle in the Southwest Pacific"
- Supervised by Helen Bostock (NIWA) and Andrew Mackintosh (ARC/SGEES).

**Sam Taylor-Offord** (MSc)
"Seismic and geodetic observations of accelerated sliding at Haupapa/Tasman Glacier, New Zealand"
- Supervised by John Townend (SGEES) and Huw Horgan (ARC/SGEES).

**Merjin Thornton** (MSc)
"The response of Brewster Glacier to five decades of climate"
- Supervised by Huw Horgan (ARC/SGEES) and Brian Anderson (ARC).

**Cassandra Trinh-Le** (MSc)
"Dry sedimentation processes in the high-elevation McMurdo Dry Valleys, Antarctica: A case study in University Valley"
- Supervised by Warren Dickinson (ARC) and Kevin Norton (SGEES).

PhD students Ross Whitmore and Jamey Stutz
David Glacier, Antarctica
Photo: Andrew Mackintosh

# SIGNIFICANT EVENTS

Overlooking Edisto Inlet, Antarctica
Photo: Jamey Stutz

# ARC RESEARCHER WINS THE MCKAY HAMMER AWARD

The 2017 Alexander McKay Hammer – the premier award of Geosciences New Zealand – has gone to the ARC's Nick Golledge.

The McKay Hammer is given to a researcher for the most meritorious contribution to geology published in the previous three calendar years. During the nomination period of 2014-2016, Nick published 24 papers dealing primarily with modelling of the Antarctic ice sheet, all in quality science journals including *Nature*, *Nature Climate Change*, and *Nature Communications*. The papers' co-authorships reveal a high level of collaboration that involves local and international scientists.

Nick joined the Antarctic Research Centre in 2009, initially on a 3-year Research Fellowship to expand the Centre's Antarctic ice sheet modelling capability. Nick took up this challenge following his PhD at the University of Edinburgh focussing on the glacial history of the United Kingdom, and subsequent years employed as a glacial geologist at the British Geological Survey. He set to work building a high-performance computing capability based in Victoria University's Faculty of Science and the School of Engineering and Computer Science.

Nick's science helps fill an important gap in New Zealand's geoscience. As a nation, we have an excellent record in the international paleo-environmental community. However, we have lacked in applying past environmental reconstructions to improve future projections of change via numerical models. This is where Nick steps in. He provides realistic simulations that employ the paleo–record to help determine future outcomes of prolonged change under natural and anthropogenic forcings. Nick is also a world leader with only a handful of other groups undertaking this type of paleo-calibrated ice sheet modelling world-wide. As well as being remarkably productive Nick also received a Rutherford Fellowship and was an AI on a successful RSNZ Marsden Fund in 2015, and is one of the science leaders in the NZ SeaRise Programme in 2017.

Nick Golledge

# NEW ARC MEMBER SELECTED AS IPCC LEAD AUTHOR

Andrew Mackintosh selected as Lead Author on the Intergovernmental Panel on Climate Change (IPCC) Special Report.

ARC Director, Andrew Mackintosh was selected from more than 500 nominations worldwide to serve as a Lead Author of the Special Report on the "Oceans and Cryosphere in a Changing Climate". The report is unique in the body's history, says Andrew.

"It reflects the increasing awareness of the changing cryosphere and oceans, and their impact on human civilisation and global ecosystems. The report will span the full range of topics from physical climate science, via changes in terrestrial and marine ecology, to human impacts including legal, economic and social dimensions."

The first Lead Author meeting was held in Nadi, Fiji, during early October 2017. Andrew is a Lead Author on Chapter 3 - "Polar Regions", which will have core sections dealing with changes in the Antarctic ice sheet and its effects on sea level, ocean circulation and ecology. Please feel free to email Andrew key papers published in this field since the 5th IPCC Assessment Report in 2013 (Andrew.Mackintosh@vuw.ac.nz).

Top: Chris Derkson (Canada), Alexey Ekaykin (Russia), Martin Sommerkorn (Norway), Andrew Mackintosh (NZ)
Bottom: Monica Muelbert (Brazil), Sandra Cassotta (Denmark), Mike Meredith (UK), Ted Schuur (USA), Anne Hollowed (USA)



# S.T. LEE LECTURE IN ANTARCTIC STUDIES

Professor Matt King presented the 2017 S.T. Lee Lecture.

The 15th annual S.T. Lee Lecture in Antarctic Studies, "Continental loss: The quest to determine Antarctica's contribution to sea-level rise" was presented by Professor Matt King on 16 October 2017.

For over 50 years scientists have been working to understand Antarctica's contribution to sea level. For much of this time there has been disagreement about whether this massive ice sheet is even growing or shrinking. Recently, advances in data analysis and computer modelling resulted in the first reconciled estimate of change showing that Antarctica is increasingly contributing to sea-level rise. During the lecture Matt explained some of the major advances that led to this reconciled estimate and highlighted some of the fascinating things we can learn about Earth from the vantage-point of Antarctica.

Matt King presenting his lecture, in Hunter Council Chamber, Victoria University
Photo: ©Image Services, VUW

Matt is Professor of Polar Geodesy at University of Tasmania working on observing and modelling the Antarctic ice sheet, sea-level change and the changing shape of Earth. Several of his papers were used to establish the physical basis of climate change within the 5th assessment report of the IPCC. His work has received international recognition most prominently when the Royal Society (London) awarded him the 2015 Kavli Medal and Lecture for his work that contributed to the first reconciled estimate of Antarctica and Greenland's contribution to sea-level change.

During his week here, Matt travelled to the University of Otago to repeat his S.T. Lee Lecture and meet with colleagues, he gave specialist talks at Victoria University and GNS Science, had media interviews with Radio New Zealand, and a reception was held for him and invited guests at the Australia High Commissioner's residence.

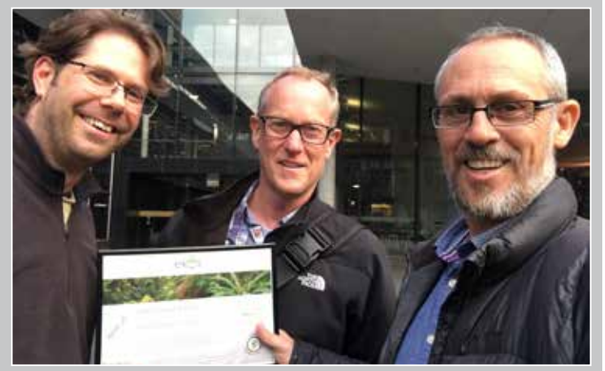
# ARC NOW CARBON NEUTRAL

The ARC now "Walks the Talk" by becoming carbon neutral.

The ARC carries out world-class research in the field of climate change. Maintaining our status as world leaders requires us to travel widely, and air travel in particular creates significant carbon dioxide emissions. One accessible way to re-claim this carbon dioxide is through a rainforest protection, carbon-offsetting scheme.

In May 2017, the ARC became the first institute at Victoria University to go carbon neutral when it purchased rainforest offsets from Ekos, a boutique carbon dioxide management company run by Sean Weaver. All Ekos carbon dioxide offsets come from the international voluntary carbon market and certified rainforest protection carbon projects, which is not simply reforestation.

Andrew Wilkes (VUW Sustainability Manager), Tim Naish (former ARC Director) and Sean Weaver (Ekos)
Photo: ©Image Services, VUW



# VICTORIA HOSTS INTERNATIONAL SYMPOSIUM ON THE CRYOSPHERE

In February around 250 delegates from more than 25 countries attended the International Symposium on the Cryosphere in a Changing Climate.

The symposium brought together three of the leading international snow and ice associations; the International Association of Cryospheric Sciences (IACS), the International Glaciological Society (IGS) and the World Climate Research Programme Climate and Cryosphere Project (WCRP CliC). It was hosted by Victoria University, and sponsored by Antarctica New Zealand, NIWA, GNS Science, and the University of Otago.

The conference consisted of a mix of plenaries and talks from experts on ice sheets, sea ice, glaciers and sea-level change, which helped to inform researchers in New Zealand about the cutting edge of science. It also allowed our own world-class researchers (and particularly students) in the ARC to present their work to an international audience.

A forum on sea-level rise, chaired by Tim Naish (ARC) and Dan Zwartz (MfE) was held in association with the conference. This provided an opportunity for government representatives and other end users (e.g. MBIE, MfE, regional councils and other regional authorities) to interact with local and visiting sea-level experts.

Michael White (Senior Editor, *Nature*) and Bronwyn Wake (Chief Editor, *Nature Climate Change*) attended the conference, providing opportunities for Victoria-based researchers to learn more about *Nature* journals, and to build personal relationships with these editors.

Andrew Mackintosh was the lead organiser of this meeting, with strong support from a New Zealand team including James Renwick (SGEES), Shaun Eaves (ARC), Heather Purdie (University of Canterbury) and Natalie Robinson (NIWA). Ian Allison (University of Tasmania) chaired the international steering committee that developed the scientific programme. Olya Albot (ARC MSc graduate) provided outstanding administrational assistance.

# THE FIRST #GREAT ANTARCTIC CLIMATE HACK

This first ever hack focussed on assessing and improving earth system models in the Antarctic/ Southern Ocean region.

In her role as steering committee member of the SCAR Research Programme AntClim21, Nancy Bertler organised as part of a team led by Joellen Russell (University of Arizona) and Thomas Bracegirdle (British Antarctic Survey) the first ever #GreatAntarcticClimateHack, hosted by Jeff Severinghaus at the Scripps Institution of Oceanography in La Jolla from 10-12 October 2017. The aim of the hack was to develop new metrics to assess and improve the performance of a new generation of earth system models as these models will provide projections for the next Intergovernmental Panel on Climate Change (IPCC) Report, including evaluations on sea level rise, ocean acidification, carbon cycle feedbacks, ocean and atmospheric warming, and ecosystem response. The workshop brought together a diverse group of experts and emerging researchers from 17 countries with backgrounds in atmospheric, oceanic, cryospheric, and biological research working on the collection of observations and data, past reconstructions, modelling experiments and future projections. The team first identified important shortcomings in current model performance and where new data are available that could support data constraint experiments. Such an approach permits models to be assessed and most importantly improved. The multidisciplinary character of the team allowed for novel approaches such as using the GPS data from Adélie penguins that rely on ocean gyres for their seasonal migration may help evaluate


the representation of such gyres and ocean currents in models. A second focus of the meeting was to train researchers with no modelling expertise how to access modelling results and to use those quantitatively. The development of user friendly portals has provided an opportunity to empower the non-modelling community to interrogate models to assist with their own research and to develop additional metrics. The team is currently working on a manuscript that details the new metrics for uptake by the Earth System Model Validation Portal (ESMVal), the gateway for IPCC model projections.



# ARC SUPPORTS INTERNATIONAL CONFERENCE ON ANTARCTICA

Latest advances and future research priorities were the focus of the SCAR Past Antarctic Ice Sheet Dynamics (PAIS) Conference.

The conference, held in Trieste, Italy from the 10-15 September 2017, was organized by Laura De Santis and ARC's Tim Naish, co-chief officers of SCAR-PAIS Programme, with major support from Istituto Nazionale di Oceanografia e di Geofisica, Antarctic Research Centre, Victoria University, Scientific Committee on Antarctic Research (SCAR), Programma Nazionale di Ricerche in Antartide (PNRA), University of Trieste and US National Science Foundation. The conference was attended by 210 scientists and students from 18 countries, 20 from New Zealand. More than half the participants were early career researchers and graduate students. The editors of *Nature Communications*, *Nature Geoscience*, and *Reviews in Geophysics* also attended the meeting - we are in discussion over a number of publications, which will provide state of the art reviews.

The conference show-cased the latest advances in Antarctic ice sheet and sea-level science and identified future research gaps and priorities. Specific emphasis was placed on the research priorities of the IPCC, Antarctic Treaty System (ATS), and the SCAR Horizon Scan. Keynote speakers from outside the PAIS community helped stimulate new multidisciplinary research directions on how Antarctic ice sheet and climate change will impact biological systems, global climate systems, and sea-level change. Richard Levy (GNS Science) gave an invited talk on how paleoclimate research informs future ice sheet projections.

The final day was dedicated to a science-policy session. SCAR president, Steven Chown, discussed his vision for how SCAR research can have more impact within both the ATS and UN frameworks. Valérie Masson-Delmotte, co-Chair of IPCC Working group 1, outlined the chapter structure and how the SCAR community could contribute to the next assessment report. Chuck Kennicutt, leader of the SCAR Horizon Scan and Council of Managers of National Antarctic Programs (COMNAP) Antarctic Roadmap Challenges project, talked about how international logistics and operations could be aligned to address the big science questions. The outcome of the conference will be a white paper that identifies new strategic directions, as the basis for a future interdisciplinary SCAR research programme.


Although the programme was demanding, our Italian hosts provided a stunning waterfront venue close to wonderful restaurants, superb logistics and social events, which resulted in a highly productive and memorable meeting. More detail on the conference programme, highlights, side events and workshops can be viewed on the website: http://www.scar-pais.org/index.php/conference

The PAIS Conference delegates
Photos: Sterle

# MUSE PRIZE COMMITTEE MEETS IN WELLINGTON

Peter Barrett chaired his last meeting of this prestigious committee in his home town.

The "Tinker-Muse Prize for Science and Policy in Antarctica" is a US$100,000 unrestricted mid-career award to an individual in the fields of Antarctic science and/or policy who has demonstrated potential for sustained and significant contributions that will enhance the understanding and/or preservation of Antarctica. It has been awarded annually since 2009, and Emeritus Professor Peter Barrett has been a member of the selection committee for 5 of its 10 meetings to date, the last three as its chair.

The Committee members are selected to cover a diversity of research fields and regions, and since 2016 were Kathleen Conlan (Marine Biologist, Canada), Vazira Martazinova (Meteorologist, Ukraine), Ronald Buss de Souza (Oceanographer, Brazil), Catherine Ritz (Glaciologist, France) and Sanjay Chaturvedi (Politics, India), with Eoghan Griffin, SCAR Executive Officer as Committee Secretary. Meetings in recent years have taken place in Punta Arenas, Shanghai, Stellenbosch, Warsaw, and Wellington.

The Committee arrived in Wellington on 19 June, and met the following day. By early afternoon a consensus had been reached, and the winner contacted – Professor Matt England (University of New South Wales). The following day an event was held to highlight the work of the Muse Prize Committee and SCAR and to thank Peter for his work on the Committee. In addition to Tinker Foundation Director Renate Rennie and SCAR's Eoghan Griffin talking about the awards, we were fortunate to have two award winners themselves, Tim Naish (2014 Muse Prize winner) and Bella Duncan (2013 SCAR student Fellowship award) talking about being a recipient.

That evening the Committee joined with members of the Wellington Diplomatic Corps at the New Zealand Antarctic Society's Mid-Winter event to acknowledge past and present Antarctic expeditions and talk with the winter-over team at Scott Base.

In Peter's words, "It was a fitting and enjoyable conclusion to an intense few days, as well as the four previous meetings. Overall, a rewarding experience through the very talented people I met and worked with both as applicants and Committee members".

The Tinker-Muse Prize Selection Committee: (L-R) Peter Barrett, Eoghan Griffin, Catherine Ritz, Renate Rennie, Sanjay Chaturvedi, Kathleen Conlan, Ronald Buss de Souza and Vazira Martazinova. Photo: Peter Barrett

# ARC VISITOR

Taryn Noble

Taryn Noble, a paleoceanographer based at the Institute of Marine and Antarctic Studies, University of Tasmania, is working to understand the role of Southern Ocean circulation on Antarctic ice sheet dynamics during past climate transitions. Taryn's current research programme is focused on reconstructing changes in ocean circulation, and in particular tracking changes in Antarctic Bottom Water, during the last deglaciation.

Taryn visited Rob McKay (ARC) and Helen Bostock (NIWA) between August and November 2017, as part of an Endeavour Postdoctoral Research Fellowship, which provides support for Australians to undertake research and professional development overseas. The aim was to build links with New Zealand experts in ocean and ice sheet history; and as an isotope geochemist, learn more about sedimentology on the Antarctic margin.

Taryn noted that she got much more out of her visit than promised to the funding agency.

"I came away with more ideas and projects than I have time for!

I thoroughly enjoyed discussions with the excellent ARC postgraduate students and ARC's sea level and ice sheet modelling experts."



# S.T. LEE YOUNG SCIENTIST EXCHANGE

The exchange programme offers a researcher the opportunity to travel between the University of Alaska Fairbanks and Victoria University.

The 2016 recipient, Eva Sutter, arrived in Fairbanks in March 2017 ready to work on a project investigating how oil leaks and spills under sea ice migrate through the ice. They were interested in seeing if this migration could be detected using the geophysical spectral induced polarization (SIP) method, whereby an alternating current gets induced at different frequencies between two current electrodes embedded in the sea ice and the potential difference is then measured between two electrodes at a larger depth. Unfortunately part way through their experiments the device stopped working and attempts to revive it were unsuccessful. Sure that the SIP method will work the instrument is being repaired and will be shipped back to do the final measurements.

If these expected SIP curve distortion occurs, they will be able to contribute to the pressing topic of oil spill detection in sea ice before surfacing – something that currently none of the known methods is capable of doing.

Eva commented that, "The research exchange to Alaska was a gain both professionally and personally, and I am grateful to have been given this opportunity to make new connections. I look forward to seeing how the experiment in the ice tanks will evolve."

Eva Sutter

# "THIN ICE" - THE JOURNEY CONTINUES

Peter Barrett reports on continuing outreach, new material and new subtitles for this unique film on climate science.

*Thin Ice* has been promoted as an aid to teaching in New Zealand secondary schools. This year we extended the film's reach through stories developed for the Science Learning Hub, and through screenings and discussions in Wellington, Otago and Nelson with support from Enviroschools.

The Science Learning Hub is a national project funded by the Government's Strategic Plan for Science in Society, and hosts a website that publishes articles aimed at helping both primary and secondary school students learn about science and science-related issues such as climate change. We worked with them on an introduction to *Thin Ice* for the classroom, and in May released ten focussed stories on various climate issues using material from and links to *Thin Ice*.

At the same time we released three new 10 minute video clips produced by the films Director, Simon Lamb, updating aspects of *Thin Ice* science and based on recent S.T. Lee lectures. These show Jane Francis on the greening of Antarctica (2013), Rob DeConto on modelling ice sheets (2014), and Eric Rignot on disappearing ice sheets (2017).

We had been finding that in the last few years of screenings and discussions interest and concern was turning from whether climate change was real to what do we do, so it was with a sense of relief that we read two reports released in March 2017 on climate solutions for New Zealand, one from the OECD and the other from GLOBE-NZ. This led to the use of *Thin Ice* as a starting point for a discussion on solutions in a series of screenings in the Wellington area and the South Island organised through Enviroschools (Otago), and Nelson Science Society (Nelson).

*Thin Ice* has also now been screened in India with Indian subtitles for the first time. The subtitling was done by our PhD student Abhijith Ulayottil Venugoapl, originally from Kerala State for screening in his home town to over 100 people on 4 May. The language Abhi chose was Malaylam, one of the 22 languages of India, and spoken by over 30 million people.

# NEW MARSDEN

A new Marsden award looks into studying past abrupt climate change in New Zealand and Patagonia to better inform our future.

Andrew Mackintosh along with ARC colleagues Brian Anderson, Shaun Eaves, Lionel Carter and SGEES Kevin Norton have been awarded nearly a million dollars by the Marsden Fund to better understand the drivers of the Antarctic Cold Reversal, an abrupt climate change that affected the southern mid to high latitudes around 14,000 years ago. Andrew and his team will be dating and reconstructing glaciers and climate in the Southern Alps and in Patagonia, and working with paleoclimate modellers to understand this societally-relevant period of Earth's recent history. Our team includes international paleoclimate modellers and data experts based in Chile (Maisa Rojas, Esteban Sagredo), Denmark (Joel Pedro), Australia (Laurie Menviel) and the USA (Feng He).

Boulders deposited by Dart Glacier, record the timing and magnitude of past climate change events
Photo: Shaun Eaves

# PHD STUDENT WINS ANTARCTICA NEW ZEALAND SCHOLARSHIP

Dan Lowry won the 2017 Antarctica New Zealand Sir Robin Irvine Postgraduate Scholarship.

This scholarship is one of only two awarded each year by Antarctica New Zealand, each of which is open to students throughout New Zealand in any discipline, who are undertaking Antarctic research. The award includes a financial contribution as well as logistics support for two field seasons.

Dan, who is supervised by ARC's Nick Golledge and Nancy Bertler, was invited to present his work at the annual Antarctic conference in Otago in June, where he was formally presented with the award.

In November, Dan headed to the Ice to work in the field with two NIWA oceanographers Craig Stevens and Mike Brewer, as part of the larger Ross Ice Shelf Project. The field site was on the central Ross Ice Shelf near the glaciological boundary between ice flowing from the West and East Antarctic ice sheets. The broader field objectives for the oceanographic component were to better understand the ocean circulation underneath the ice shelf and identify any freezing or melting occurring at the ice-ocean interface. More specifically, we were interested in observing the structure of the ocean cavity below the ice shelf in terms of temperature and salinity, the impact of the tidal cycle on the circulation and if the roughness of the ice shelf bottom created turbulence.

The team successfully deployed a mooring down the drilled boreholes that is currently transmitting temperature, salinity, and current speed data to NIWA via iridium communications. They also obtained camera footage through the ice shelf, all the way down to the sea floor. They made a number of exciting discoveries, including observing some recent re-freezing on the ice shelf bottom. This new data will help us better understand modern oceanographic processes in the Ross Ice Shelf cavity, which is useful for both interpreting the geologic record of the past and predicting future ice shelf changes.

Dan Lowry



# ARC ENDOWED DEVELOPMENT FUND

The ARC Endowed Development Fund has awarded 87 grants to postgraduate students since its inception in 2004.

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

The 2017 recipients were:

**Hannah Chorley, Lukas Eling, Georgia Grant, Dan Lowry, Jamey Stutz, Abhijith Ulayottil Venugoapl, and Laurine van Haastrecht** — to attend the Past Antarctic Ice Sheet Dynamics (PAIS) Conference in Trieste, Italy.

**Bella Duncan and Cassandra Trinh-Le** — for writing papers on their respective PhD and MSc research.

**Katelyn Johnson** — to attend the Karthaus Ice and Climate Summer School in Italy in September.

**Dan Lowry and Laurine van Haastrecht** — to attend the Delft Summer School on sea level change in The Netherlands in September.

**Morgan Smith** — for laboratory analyses.

**Jamey Stutz** — to travel to Durham University, UK, to work with modelling experts.

**Abhijith Ulayottil Venugoapl** — to attend the Antarctic Climate Summer School in Goa, India in May.

**Lauren Vargo** — to present at the American Geophysical Union (AGU) Fall Meeting in New Orleans, USA in December.

Georgia Grant preparing for her talk at the PAIS Conference, Photo: Serle

# AWARDS AND APPOINTMENTS

In 2017 ARC staff and students were awarded the following:

## Awards

**Gavin Dunbar** — University Research Fund.

**Dan Lowry** — Antarctica New Zealand Sir Robin Irvine postgraduate Scholarship.

**Andrew Mackintosh** — Deep South National Science Challenge.

**Andrew Mackintosh** — Royal Society of New Zealand Marsden Fund.

**Andrew Mackintosh** — NZARI Fund.

**Tim Naish** — MBIE Endeavor Fund.

**Jamey Stutz** — Antarctic Science International Bursary.

**Lauren Vargo** — "Best student talk" in the Beanland-Thornley Student Talks.

**Lauren Vargo** — Royal Society Bates Scholarship.

## Promotions

**Huw Horgan** — Promoted within the Senior Lecturer scale in the 2017 Academic Promotion Round.

**Andrew Mackintosh** — Promoted to Professor in the 2017 Academic Promotion Round.

**Rob McKay** — Promoted to Associate Professor in the 2017 Academic Promotion Round.

## Appointments

**Nancy Bertler** — Appointed to the Rutherford Discovery Fellowship Interview Panel.

**Andrew Mackintosh** — Selected as IPCC Lead Author on the Special Report on Oceans and the Cryosphere in a Changing Climate

# FINANCIAL SUMMARY

Helm Point on Honeycomb Ridge, Admiralty Mountains, Antarctica
Photo: Cliff Atkins

# FINANCIAL SUMMARY

The ARC has continued to build up revenue with a record total of $3.28 million - $640 thousand up on the previous year.

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

In 2017, the ARC received a total of $3.28 million in revenue and a corresponding expenditure of $2.86 million. The cost centre budget had a $8.5 thousand deficit, however, the ARC's research funding contribution to the University via overheads from grants was $384 thousand, thus overall the ARC contributed $375 thousand of revenue to the University.

## New funding success

The ARC successfully secured the following new funding in 2017:

**MBIE Endeavor Fund**
"Improved sea-level rise projections for New Zealand to better anticipate and manage impacts"
- $7.1 million over five years
- PI: Tim Naish

**Deep South, National Science Challenge**
"Impact of climate change on frozen water resources"
- $389 thousand over two years
- PI: Andrew Mackintosh

**Marsden Fund**
"Did a previous collapse of the Antarctic ice sheet cause abrupt climate change in the Southern Hemisphere?"
- $960 thousand over three years
- PI: Andrew Mackintosh

**NZARI Fund**
"Potential for non-linear, threshold-driven response of Antarctic outlet glaciers: Insights from David Glacier, Antarctica"
- $80 thousand over 2.5 years
- PI: Andrew Mackintosh

**University Research Fund**
"Ultra-high resolution paleo-climate reconstructions from Southern New Zealand"
- $28,500 thousand over one year
- PI: Gavin Dunbar

**Research Office**
"Salary Support for Shaun Eaves"
- $32 thousand over three years
- PI: Shaun Eaves

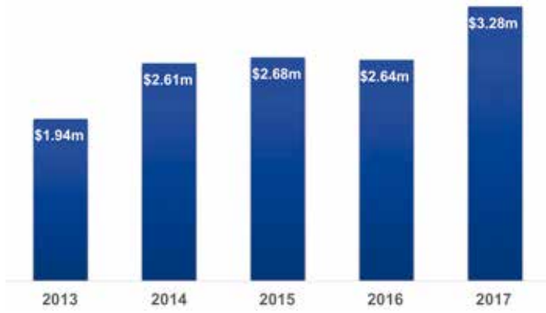
**Antarctic Science International Bursary**
"Support for travel to Durham University"
- $4 thousand over one year
- PI: Jamey Stutz

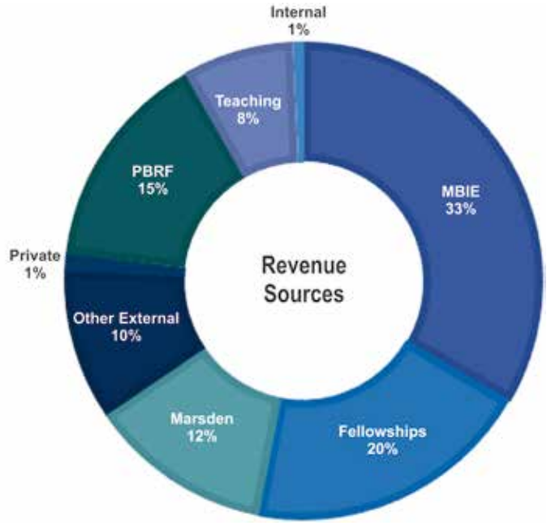
## Our revenue

In 2017, the ARC received 75% of its funding from external sources. A third ($1.09m) comes from the Ministry of Business, Innovation and Employment (MBIE) through programmes such as our new Endeavour fund, the Deep South National Science Challenge and via sub-contracts with our research partners at GNS Science and NIWA. Our next highest source ($644k) was from our four prestigious Rutherford Fellowships and a James Cook Fellowship. The funding for four of our six Marsden grants came to an end in early 2017 therefore contributing only 12% ($409k) of our revenue. The 10% from 'other external' funding includes $136k of NZARI funding, $43k from the International Cables Protection Committee, and $157k from other national and international organisations.

The remaining 25% of revenue is made up of PBRF, Teaching, Internal and Private grants. PBRF (Performance-Based Research Fund) contributed 15% ($490k) and is calculated by Victoria University based on external research funding that meets 'PBRF' criteria and the quality rating of staff. The 8% teaching portion ($245k) came from SGEES for teaching and supervision by ARC staff, based on hours, as well as a proportion of PBRF graduate completion income. Internal funding ($24k) is University funded grants for staff and students and Private revenue is the interest from donations held by the Victoria University Foundation that have been transferred to the Research Trust for our Endowed Development Fund grants.

Our revenue has increased significantly since the dip in 2013 from the loss of a major research programme. Revenue recovered in 2014 and remained stable over the next three years with the start of four new Marsden grants and a Rutherford fellowship and has since peaked with an additional $640 thousand in 2017 as new funding has been secured.

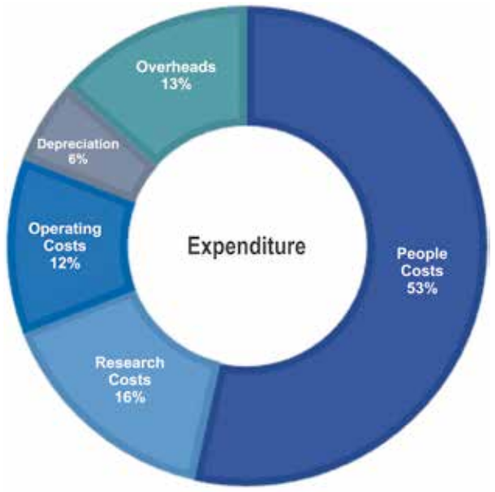


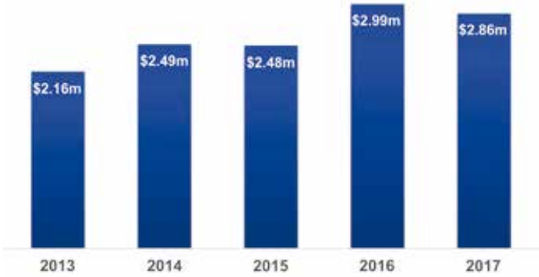




## Our expenditure

Just over half of the ARC's expenditure ($1.53m), is related to staff costs associated with salaries and promotions, annual leave, ACC and superannuation. The next highest expense is our research costs at 16% ($446k). These are the costs directly associated with research projects such as fieldwork expenses, sub-contracts, student scholarships, analyses, and conference attendance. The ARC's Research Trust grants contributed $245k of Research Office overheads and $139k of University overheads. These are transferred directly from grants to cover services provided by the Research Office and central University. Our 12% towards 'operating costs' are related directly to our Centre budget and included $182k for office/storage space charged by the University and $156k associated with running the Centre, including leasing computers, phones, printing, and stationary. Depreciation of CAPEX equipment increased in 2017 to $163k due to the capitalisation of our new Hot Water Drill, however this was offset by additional revenue from NZARI to cover this increase.

Variations in the overall expenditure over the last five years has been primarily due to staff changes in FTE, and pay-rises/promotions and depreciation costs as assets have been written-off and new items purchased.



# OUTREACH

Tasman Lake, New Zealand
Photo: Shaun Eaves

# OUTREACH

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

## Media interviews

**95 bfm Radio:** 14 July, "Ice Ice Broken - Implications of the one trillion tonne iceberg that calved off the Antarctic Peninsula", Andrew Mackintosh and Nancy Bertler. http://www.95bfm.com/bcast/ice-ice-broken

**Air New Zealand 'Where to Next':** promotional Antarctic science video in conjunction with Antarctica New Zealand featuring Gavin Dunbar & drilling team for the Ross Ice Shelf drilling project.

**Antarctic Magazine Vol35(4):** "What does the United Nations Paris Climate Agreement mean for Antarctic?: Implications for New Zealand's future research priorities", Tim Naish.

**BBC Documentary 'New Zealand: Earth's Mythical Islands':** 19 January and 29 Oct 29, Brian Anderson.

**Cosmos Magazine:** 18 April, "How high will global sea levels rise?", Nick Golledge. https://cosmosmagazine.com/climate/how-high-will-global-sea-levels-rise

**Newsroom:** 12 December, "Drowning dreams: Billions at stake as Govt mulls sea level rules", Tim Naish.

**NZ Herald:** 12 July, "Kiwi scientists help build 'goldmine' climate database", Nancy Bertler. http://www.nzherald.co.nz/nz/news/article.cfm?c_id=1&objectid=11889027

**NZ Herald:** 14 July, "Q&A: Antarctica's new trillion-tonne iceberg", Nancy Bertler. http://www.nzherald.co.nz/nz/news/article.cfm?c_id=1&objectid=11890071

**NZ Herald "The Big Read":** 23 October, Our slow moving disaster as sea level rises". Tim Naish on new MBIE NZ SeaRise programme.

**NZ Herald:** 5 November, "Alarming climate report bodes badly for Paris goals - NZ scientists", Nancy Bertler, Richard Levy (GNS Science), Jocelyn Turnbull (GNS Science). http://www.nzherald.co.nz/nz/news/article.cfm?c_id=1&objectid=11940654

**NZ Herald:** 14 December, "NZ's glaciers have shrunk by a third in area", Brian Anderson. http://www.nzherald.co.nz/nz/news/article.cfm?c_id=1&objectid=11959777

**NZ Herald:** 21 December, "Kiwi-led scientists prepare to drill vast ice sheet in Antarctica", Rob McKay.

**Otago Daily Times/Greymouth Star:** 14 December, "Glacier's retreat ceases, begins advance", Brian Anderson. https://www.odt.co.nz/regions/west-coast/glaciers-retreat-ceases-begins-advance

**Prime TV "Back Benches":** "Paris agreement/US pull out", Tim Naish

**Radio NZ:** 23 February, "The unusual case of the 'growing' glaciers", Andrew Mackintosh. https://www.radionz.co.nz/national/programmes/ourchangingworld/audio/201834024/the-unusual-case-of-the-'growing'-glaciers

**Radio NZ:** 1 March, "The mystery of growing glaciers", Andrew Mackintosh. https://www.radionz.co.nz/national/programmes/ninetonoon/audio/201834991/the-mystery-of-growing-glaciers

**Radio NZ:** 14 March, "South Dunedin could sink below sea level in 17 years", Tim Naish comments on Prof Flynn's predictions. https://www.radionz.co.nz/news/national/326568/south-dunedin-could-sink-below-sea-level-in-17-years

**Radio NZ:** 12 July, "Huge new climate database charts 2000 years of temperature", Nancy Bertler. http://www.radionz.co.nz/news/national/335001/huge-new-climate-database-charts-2000-years-of-temperatures

**Radio NZ:** 13 July, "Trillion-tonne iceberg breaks off Antarctica", Andrew Mackintosh. https://www.radionz.co.nz/national/programmes/ninetonoon/audio/201850933/trillion-tonne-iceberg-breaks-off-antarctica

**Nature Careers:** 20 June, "Working in NZ", Nick Golledge.

**NewsHub:** 14 March, "'Thousands' of Dunedin homes to be lost to rising sea", Tim Naish comments on Prof Flynn's predictions.

**Stuff:** 21 March, "Sea-level rise could swamp some New Zealand cities", Tim Naish on National Geographics interactive map.

**The Independent:** 13 July, "West Antarctic ice sheet could raise global sea level by three meters, warns scientist", article by Ian Johnston with contributions by Nancy Bertler. http://www.independent.co.uk/environment/antarctic-larsen-ice-shelf-collapse-sea-levels-increase-three-metres-catastrophic-collapse-climate-a7839371.html

**TVNZ 'Breakfast':** 12 July, "Climate data treasure chest", Nancy Bertler.

**TNVZ 'One News':** 29 June, article based on the big issues at the Antarctic Science Conference in Dunedin, Tim Naish, Richard Levy (GNS Science) and Gary Wilson (University of Otago).

**TVNZ 'One News':** 14 July, "Massive iceberg which broke off from Antarctica could 'cause problems for wildlife' - researcher", Andrew Mackintosh.

**TVNZ 'One News':** 14 November, Part of a COP22 series of climate change features, Tim Naish comments on sea level rise.

**TVNZ Re:News:** 17 October, "Glaciers are f*cked", Brian Anderson. https://www.facebook.com/renewsnz/videos/225298608003644/

**Twizel Update:** 20 July, "Lake Ohau drilling update", Gavin Dunbar.

## Talks to stakeholders and policymakers

**Antarctic Consultative Treaty Meeting:** 24 May, Presented the SCAR Science Lecture – "What does the Paris Climate Agreement mean for Antarctica", Tim Naish.

**Antarctic Society mid-winter celebration:** 4 July, "What does the United Nations Paris Climate Agreement mean for Antarctic?: Implications for New Zealand's future research priorities", Tim Naish.

**Argentina Ambassador visit:** 1 June, Andrew Mackintosh met with Mr Fausto Lopez Crozet.

**Australian High Commissioners Function:** 17 October, reception invite to Andrew Mackintosh and Tim Naish.

**Green Party Meeting - James Shaw:** 15 February, brief on sea-level rise and ice sheets, Eric Rignot and Tim Naish.

**Green Party - James Shaw & Eugenie Sage visit:** 18 January, "Antarctic Research Centre science", Nick Golledge, Nancy Bertler, Lionel Carter, Rob McKay, Peter Barrett, James Renwick (SGEES) and Richard Levy (GNS Science).

**Hutt City Council - Environmental Advisory Group:** 21 September, "Sea-level rise projections – Impacts for the Greater Wellington Region", Nancy Bertler.

**Labour Party - Megan Woods:** 16 February, brief on sea-level rise and ice sheets, Eric Rignot and Tim Naish.

**Tinker-Muse Prize Committee:** 8 June, "Life after being awarded the 2014 Tinker-Muse Prize for Antarctic science and policy", Tim Naish.

## Schools, public & community groups

**Alexandra Community Centre:** 30 June, "Thin Ice and panel discussion", Peter Barrett.

**Catalyst, Queenstown:** 2 July, "Trump on *Thin Ice* - Fresh hope for climate change", Peter Barrett.

**Climate Challenge, VUW:** 4 June, "The Power of Film: THIN ICE– the Inside Story of Climate Science", Peter Barrett.

**Climate Karanga Marlborough:** 22 April, "Climate change and our future: Why we need zero carbon emissions by 2050", Peter Barrett.

**Day of Science - Te Papa:** 12 May, "Antarctic research", Nancy Bertler and Hannah Brightley.

**Eastbourne Kea Scouts:** 7 August, "Visit to Ice Core Facility", Jocelyn Turnbull (GNS Science) and Nancy Bertler.

**Gros Cap and Catawba Springs Elementary schools:** 15 November, "Introduction to Antarctica: Virtual classroom visit", Jamey Stutz.

**Hutt City Library Public Presentation:** 23 March, "Future sea-level rise and implications for New Zealand", Nancy Bertler.

**Hutt STEMM Festival:** 7 May, Jamey Stutz and Katelyn Johnson on Antarctic field work:

**Innovative Young Minds:** 12 July "A STEM career in paleoclimatology", Katelyn Johnson.

**Kelburn School "Coding Club":** ongoing, Lauren Vargo support with teaching coding to primary school children.

**Lower Hutt War Memorial Library:** 19 January, "60 years of New Zealand scientific endeavour in Antarctica - What we learned and why it is important" Nancy Bertler.

**Lower Hutt War Memorial Library:** 13, 16, 19 May, "Thin Ice and discussion", Peter Barrett.

**Ministry for Education 'Mahi-Tahi - Captured in Ice by Veronika Meduna':** November, features Nancy Bertler's ice core work with a focus on RICE.

**MS Swaminathan Research Foundation (MSSRF) *Thin Ice* screening and Q&A:** 6 May, "Antarctica and warming world', Abhijith Ulayottil Venugoapl, Peter Barrett and Nancy Bertler.

**Nelson Science Society:** 29 August,"Thin Ice: the Inside Story of Climate Science", Peter Barrett.

**Nelson Science Society:** 14 November, "Climate change: Reason for hope", Peter Barrett.

**New Plymouth Boys High:** 12 June, Lionel Carter.

**Otaki Probus:** 13 August, "Ten things you didn't know about climate change", Tim Naish.

**Pirongia Lions Club:** 16 May, "An ordinary job in an extraordinary place", Darcy Mandeno.

**Ponsonby Anglican Church:** 20 August, "Climate Change – The Moral Imperative of our time", Tim Naish.

**Probus Club of Kapiti Coast:** 21 November, "Climate change, polar ice sheets and rising sea-levels", Tim Naish.

**Queen Margaret College:** 4 July, two presentations "#BelieveYouCan" and "Science for a more resilient and prosperous New Zealand – The impact of Sea Level Rise on New Zealand", Nancy Bertler.

**SGEES Hands-on-Geo Day:** August, "Earth vs Mars" for Wellington high-school students, Shaun Eaves.

**Sir Homes Miller Memorial Lecture 2017 - New Zealand Antarctic Society:** 23 November, "Antarctic science priorities in a post-Paris world", Tim Naish.

***Sonne* Research Vessel Tour:** 25 January, Gavin Dunbar on Antarctic Research Centre booth.

**Space Place "Far from Frozen" Exhibition:** 8 July-6 August, Tim Naish, Nick Golledge, Huw Horgan, Peter Barrett, Jamey Stutz and Ross Whitmore.

**Teatro Miela High School, Trieste:** 14 September, "Antarctic Earth Science - continuing surprises", Peter Barrett.

**University of the Third Age (U3A):** 22 September, "Antarctica, the Southern Ocean and a cold day in Wellington", Lionel Carter.

**Wanaka Festival of Colour:** 9 April, "Antarctica: Beautiful but melting" Tim Naish.

**Wellington Tramping and Mountaineering Club:** 31 January, "Surface elevation changes in Antarctic outlet glaciers through time", Ross Whitmore.

**Winona State University 'Earth Talks':** 25 April, "Field work in Antarctica: Warmer than you would think", Ross Whitmore.

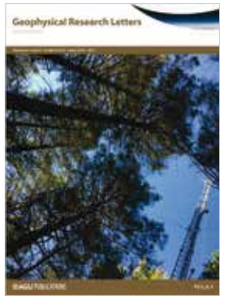
**Winona State University 'Earth Talks':** 11 September, "Reconstructing Holocene fluctuations of Mawson, Tucker, and Ironside glaciers, Antarctica", Ross Whitmore.

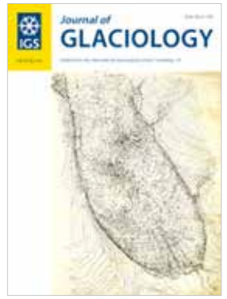
**Zealandia:** 26 April, "Thin Ice and discussion", Peter Barrett.

# PUBLICATIONS, CONFERENCES & COLLABORATORS

Ross Ice Shelf Project traverse, Antarctica
Photo: www.neilsilverwood.com

# PUBLICATIONS, INVITED PRESENTATIONS AND WORKSHOPS






## Peer-reviewed publications - 31


Bakker, P., Clark, P.U., **Golledge**, N.R., Schmittner, A., Weber, M.E., (2017). Centennial-scale Holocene climate variations amplified by Antarctic Ice Sheet discharge. *Nature* 541(7635): 72-76. doi:10.1038/nature20582

**Bertler**, N., Levy, R., and Turnbull J., (2017). Discovery of ancient atmospheres in Antarctic ice. In *WMO Greenhouse Gas Bulletin, The State of Greenhouse Gases in the Atmosphere based on the Global Observations through 2016* 13: 4-5, ISSN2078-0796

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## Invited keynote/plenary presentations


**Anderson**, B., (2017). Chasing glaciers. *Southern Hemisphere Alpine Conference*, Christchurch, New Zealand, 17-18 June.

**Barrett**, P.J., (2017). The role of film in climate science communication. *Past Antarctic Ice Sheet Dynamics (PAIS) Conference*, Trieste, Italy, 11-15 September, 2017.

**Carter**, L., (2017). Southern Ocean - Antarctica with New Zealand. *Postgraduate Certificate in Antarctic Studies*, University of Canterbury, New Zealand, 17 January, 2017.

**Carter**, L., (2017). Modern and future change in a Zealandian Ocean. *Searching for Tropical Zealandia Workshop*, GNS Science, Lower Hutt, New Zealand, 28 March, 2017.

**Carter**, L., (2017). Why study the New Zealand Quaternary? *Quaternary Techniques Workshop*, GNS Science, Lower Hutt, New Zealand, 18-19 May, 2017.

**Carter**, L., (2017). There are none so blind as those who ignore history. IODP Masterclass. 4 December, 2017

**Eaves**, S.R., (2017). Reconstructing climate using glaciers. *Quaternary Techiques Workshop*, GNS Science, Lower Hutt, New Zealand, 18-19 May, 2017.

**Mackintosh**, A., (2017). Estimating the contribution of glaciers to sea-level rise. *Future Sea Level and Coastal Impacts Workshop*, University of Tasmania, Hobart, Australia, 15-17 November, 2017.

**Naish**, T., (2017). The role of ocean forcing on Antarctic ice sheet stability. *Physical Oceanography Workshop*, Wellington, New Zealand, 17-18 August, 2017.

**Naish**, T.R., Rintoul, S., Siegert, M., Chown, S., Xavier, J., Fricker, H., DeConto, R., Masson-Delmotte, V., England, M., Wilson, G., Gilbert, N., (2017). Antarctica and the Southern Ocean in 2067: What future will we choose? *Past Antarctic Ice Sheet Dynamics (PAIS) Conference*, Trieste, Italy, 11-15 September, 2017.


## Chaired Workshops


**Barrett**, P. (2017). Movies and science communication with *Thin Ice - the Inside Story of Climate Science*. *APECS Science Communication Workshop*, Trieste, Italy, 11-15 September, 2017.

**Bertler**, N.A.N., (co-chair) (2017). *The Inaugural #GeatAntarcticClimateHack*, Scripps Institution, La Jolla, USA, 9-12 September, 2017.

Entorneau, J., Escutia, C., **McKay**, R., **Bertler**, N., (Chairs) (2017). Holocene climate variability off Wilkes Land, East Antarctica and integrating coastal ice cores with high resolution sediment records (closed meeting). *Past Antarctic Ice Sheet Dynamics (PAIS) Conference*, Trieste, Italy, 10-15 September, 2017.

**McKay**, R., (Chair), Exon, N., Mueller, D., Gohl, K., Gurnis, M., Henrys, S., Inagaki, F., Pandey, D., Shevenell, A., Whiteside, J., van de Flierdt, T., **Naish**, T., Heuer, V., Morono, Y., Coffin, M., Godard, M., Wallace, L., Kodaira, S., (2017). Developing community-based scientific priorities and new IODP proposals. *Australasian IODP Regional Planning Workshop*, Sydney, Australia, 13-16 June, 2017.

**Stutz**, J., (Chair), Baroni, C., Busetti, M., Kawamata, M., Khim, Boo K., Kim, Y., Jamieson, S., Sauli, C., (2017). Terrestrial-marine regional glacial history, Terra Nova Bay area. *Past Antarctic Ice Sheet Dynamics (PAIS) Conference*, Trieste, Italy, 10-15 September, 2017.

# STUDENT CONFERENCES

## Oral presentations

**Brightley**, H. and **Bertler**, N., (2017). Reconstructing the Little Ice Age climate conditions in the eastern Ross Sea using major ion analyses from the Roosevelt Island Climate Evolution (RICE) ice core. *International Symposium on The Cryosphere in a Changing Climate*, Wellington, New Zealand, 13-17 February, 2017.

**Grant**, G., **Naish**, T., **Dunbar**, G., Sefton, J., Morgan, H., Hayward, B., Tapia, C., Kamp, P., Kominz, M., Stocchi, P., Seward, D., (2017). Amplitude and frequency of Pliocene (3.2-2.6 Ma) glacio-eustatic, sea-level fluctuations from a new shallow-marine sediment record, Whanganui Basin, New Zealand. *Past Antarctic Ice Sheet Dynamics (PAIS) Conference*, Trieste, Italy, 10-15 September, 2017.

**Grant**, G., **Naish**, T., **Dunbar**, G., Tapia, C., Morgan, H., Hayward, B., Kamp, P., Kominz, M., Seward, D., Stocchi, P., Alloway, B., (2017). Mid-Pliocene sea-level reconstructions from the Whanganui Basin, New Zealand. *Regional Sea Level Changes and Coastal Impacts Conference*, New York City, USA, 10-14 July, 2017.

**Liston**, M., Bostock, H., **Dunbar**, G., Harper, M., (2017). Glacial-Interglacial productivity at the polar front, southwest Pacific sector of the Southern Ocean. *Geological Society of New Zealand Conference*, Auckland, New Zealand, 28 November-1 December, 2017.

**Lowry**, D.P., **Golledge**, N.R., and **Bertler**, N.A.N., (2017). Climate-forced ice sheet modelling of the Ross Ice Shelf. *International Symposium on The Cryosphere in a Changing Climate*, Wellington, New Zealand, 13-17 February, 2017.

**Lowry**, D., **Golledge**, N., and **Bertler**, N.A.N., (2017). Transient ice sheet simulation of the Ross Ice Shelf deglaciation. *Past Antarctic Ice Sheet Dynamics (PAIS) Conference*, Trieste, Italy, 10-15 September, 2017.

**Vargo**, L., **Anderson**, B., **Horgan**, H., **Mackintosh**, A., Lorrey, A., (2017). Quantifying glacier fluctuations and climate drivers in New Zealand using modern and historic oblique photography, *International Symposium on The Cryosphere in a Changing Climate*, Wellington, New Zealand, 13-17 February, 2017.

**Vargo**, L., **Anderson**, B., **Horgan**, H., **Mackintosh**, A., Lorrey, A., Thornton, M., (2017). Measuring past glacier fluctuations from historic photographs geolocated using Structure from Motion. *American Geophysical Union Fall Meeting*, New Orleans, USA, 11-15 December, 2017.

## Poster presentations

**Chorley**, H., Levy, R., and **Naish**, T.R., **(2017).** Sequence stratigraphy and facies analysis of the Friis Hills Drilling Project drillcore: Towards a reconstruction of Early to Mid-Miocene East Antarctic Ice Sheet variability. *Past Antarctic Ice Sheet Dynamics (PAIS) Conference*, Trieste, Italy, 10-15 September, 2017.

**Eling**, L., (2017). Antarctic Holocene climate variability – drivers and consequences as captured by the RICE major ion record. *International Symposium on The Cryosphere in a Changing Climate*, Wellington, New Zealand, 13-17 February, 2017.

**Eling**, L., **Bertler**, N.A.N., **McKay**, R., **Pyne**, R., (2017). Early Holocene climate variability in the Eastern Ross Sea – Initial results from the major ion analysis of the RICE Ice Core. *Past Antarctic Ice Sheet Dynamics (PAIS) Conference*, Trieste, Italy, 10-15 September, 2017.

**Johnson**, K.M., **McKay**, R., **Bertler**, N.A., Albot, A., (2017). Determining the Holocene seasonality of diatomaceous laminae in the Adélie Basin and the implications for multi-record reconstructions. *International Symposium on the Cryosphere in a Changing Climate*, Wellington, New Zealand, 13-17 February, 2017.

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**Stutz**, J., **Mackintosh**, A., Norton, K., **Whitmore**, R., (2017). Potential non-Linear, threshold driven response of Antarctic outlet glaciers: Insights from David Glacier, Antarctica. *New Zealand Antarctic Science Conference*, Dunedin, New Zealand, 26-28 June, 2017.

**Stutz**, J., **Mackintosh**, A., Norton, K., **Whitmore**, R., Jones,R., Jamieson, S., Seong, Y., Lee, J., **McKay**, R., Balco, G., (2017). Potential non-Linear, threshold driven response of Antarctic outlet glaciers: Insights from David Glacier, Antarctica. *Past Antarctic Ice Sheet Dynamics (PAIS) Conference*, Trieste, Italy, 10-15 September, 2017.

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**Ulayottil Venugoapl**,A., **Bertler**,N., and Cortese,G., (2017). Glacial Antarctic warm events as captured by RICE ice core. *Past Antarctic Ice Sheet Dynamics (PAIS) Conference*, Trieste, Italy, 10-15 September, 2017.

**van Haastrecht**, L. N., **Golledge**, N., **Horgan**, H., Robel, A., (2017). Simplified models of the West Antarctic Ice Sheet with differing boundary conditions. *Past Antarctic Ice Sheet Dynamics (PAIS) Conference*, Trieste, Italy, 10-15 September, 2017.

**van Haastrecht**, L.N., **Horgan**, H., and **Golledge**, N., (2017). The presence and implications of a regional seismic unconformity beneath the Siple Coast ice streams, West Antarctica. *International Symposium on The Cryosphere in a Changing Climate*, Wellington, New Zealand, 13-17 February, 2017.

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**Whitmore**, R., **Mackintosh**, A., Norton, K., Atkins, C., **Stutz**, J., Hamilton, J., (2017). Terrestrial cosmogenic sampling in Victoria Land, Antarctica: Tucker and Ironsides glaciers. *New Zealand Antarctic Science Conference*, Dunedin, New Zealand, 26-28 June, 2017.

Ross Ice Shelf Project drill site, Antarctica
Photos: Jane Chewings



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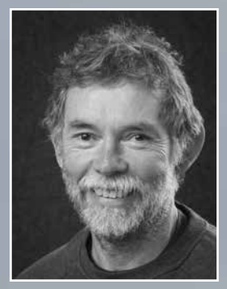

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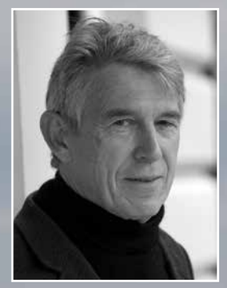

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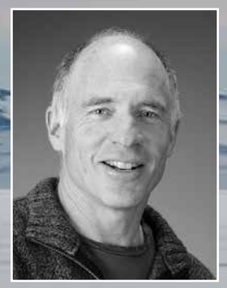

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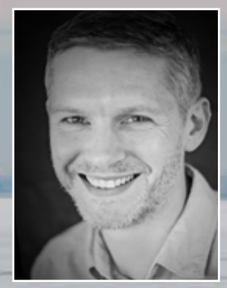

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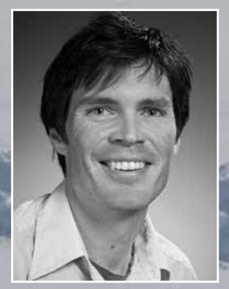

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Sedimentology & paleoclimatology

**Dao Polsiri**
Administrator



## Graduate students

| | | |
|---|---|---|
| Hannah Chorley | PhD | Antarctic climatology |
| Bella Duncan* | PhD | Paleoceanography |
| Lukas Eling | PhD | Paleoclimatology |
| William Gonzalez | PhD | Palynology |
| Georgia Grant | PhD | Sedimentology |
| Florence Issacs | PhD | Antarctic climatology |
| Katelyn Johnson | PhD | Ice core climatology |
| Wei Ji Leong | PhD | Glaciology |
| 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 |
| Ross Whitmore | PhD | Glaciology |
| Olya Albot* | MSc | Paleoceanography |
| Hannah Brightley* | MSc | Paleoclimatology |
| Lisa Dowling | MSc | Glaciology |
| Libby Galbraith* | MSc | Paleoclimatology |
| Melanie Liston | MSc | Paleoceanography |
| Karsten Lorentz | MSc | Glaciology |
| Charles Maxson* | MSc | Marine geology |
| Simon Reeve | MSc | Paleoclimatology |
| Sam Taylor-Offord* | MSc | Glacial geophysics |
| Merjin Thornton* | MSc | Glacial geophysics |
| Cassandra Trinh-Le* | MSc | Sedimentology |

*thesis submitted in 2017

## Associated researchers

| | | |
|---|---|---|
| Cliff Atkins | Senior Lecturer in Earth Sciences | Sedimentary processes and environments |
| Michael Hannah | Associate Professor in Earth Sciences | Marine palynology |
| Kevin Norton | Senior Lecturer in Geography | Geomorphology and geochemistry |
| Rebecca Priestley | Senior Lecturer - 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 | Research Associate in Geology | Freshwater algae |
| Malcolm Ingham | Senior Lecturer in Physics | Properties of sea ice |
| Mark McGuinness | Reader in Mathematics | Modelling |
| Joanna Mossop | Senior Lecturer in Law | International law |
| Nigel Roberts | Adjunct 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 |
| Cath Wallace | Teaching Fellow in Environmental Economics | Antarctic environmental issues |

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Ian Simpson, GNS Science
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Prue Williams, Ministry of Business, Innovation & Employment

## ARC Adjuncts

| | |
|---|---|
| James Bendle | Barrie McKelvey |
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| Stuart Henrys | Peter Webb |
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Ironsides Glacier, Antarctica
Photo: Ross Whitmore

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