Antarctic Research Centre

ANNUAL REVIEW 2012

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

DIRECTOR'S SUMMARY

Ross Sea from Kar Plateau, Antarctica - Photo: Richard Jones

This is the fifth Directors Summary I have written, and for me 2012 stands out as one of our most successful years. Quite appropriately, at the top of the list of achievements is the success of ice core drilling operations in the Ross Sea at Roosevelt Island, led by Nancy Bertler. The very high quality of the cores and the success of our new drill system is testament to the technical expertise of Alex Pyne and Darcy Mandeno, who designed the drill based on the Danish drill used in Greenland for the NEEM ice coring project. The project was five years in development, included five field seasons in Antarctica and Greenland, and involved a close partnership with GNS Science and Antarctica New Zealand. It is hard not to overstate the scientific and technical significance of their success, which will provide a unique archive of Ross Sea climate and ice sheet retreat since the last ice age.

2012 was also a record year for scientific outputs with staff and students publishing 37 scientific papers in leading journals including, *Nature*, *Nature Geoscience*, *Nature Climate Change*, *Proceedings of the National Academy of Sciences*, *Geology*, *Quaternary Science Reviews*, *Geophysical Research Letters*, *Earth and Planetary Science Letters* and *Paleoceanography*. We also celebrated the achievement of the completion of eight post graduate theses (2 PhD and 6 MSc).

This year we take a slight change in format with the annual review, which is intentionally reflective and highlights our successful research approach developed over the last 10 years. We outline how our integrated, multidisciplinary approach has provided some fundamental insights into the response of ice sheets, glaciers, oceans and the climate system to global warming, and how that knowledge is transferred to practitioners, the public and policymakers.

Our staff of 17 is now a well-balanced mix of experience, technical expertise and vibrant emerging talent. While senior members, Lionel Carter and Peter Barrett, still make highly-valued contributions and provide insightful advice, it's great to see a dynamic group of young researchers and academic staff, armed with the latest knowledge and tools, developing. We would like to acknowledge Peter Barrett's retirement at the end of 2012, but look forward to his continuing association as a part-time researcher and Emeritus Professor. A formal event to celebrate Peter's contribution and retirement will take place in 2013. A really enjoyable aspect of the ARC was our 25 postgraduate students who collectively bring a wide range of backgrounds and interests with nearly half of our students coming from overseas. The ARC group remains very committed to science communication through public outreach and advice to government officials and policymakers as well as the delivery of relevant outcomes for end-users, such as other science providers, local authorities, government agencies, industry, and international Antarctic and climate change stakeholders. I am always impressed by the skill and enthusiasm, not to mention the time and energy, our researchers put into communication and outreach. In this review we outline an impressive array of television, print and radio media, public lectures, school visits and outreach events undertaken by ARC staff and students this year.

A highlight of public outreach was the ARC's involvement in the inaugural NZ IceFest, which Victoria University helped sponsor. Michelle Dow co-ordinated our contribution to the month-long festival, held in Hagley Park, with staff and students involved in various scientific presentations, public debates and kids activities. Another education and outreach highlight was the *Our Far South* voyage to Antarctica led and co-ordinated, by ARC friend and philanthropist Dr Gareth Morgan. Dan Zwartz, Lionel Carter and Rhian Salmon (SGEES) took part in the expedition, which included 10 scientific experts on the region and 40 everyday New Zealanders wanting to learn more.

We also celebrated success in 2012 with Lionel Carter being awarded the New Zealand Association of Scientist's highest accolade, the Marsden Medal, by Minister of Science Hon. Steven Joyce, for his lifetime contribution to ocean science. Nick Golledge also won a highly competitive Marsden Grant to support his research on Antarctic outlet glaciers.

I'd like to end this summary with a stock take of my last five years as Director of the ARC, and some observations, challenges and opportunities for the next five years. In this Review we present a summary of revenue and expenditure over the last five years which shows large growth and some important trends. Over this period our annual revenue has increased by $800,000 and our staff numbers have increased from 12 to 17. While our revenue has kept pace with our expenditure (or vice versa), we now face a challenging funding environment for research and innovation in New Zealand, especially in a post global financial crisis and Christchurch earthquake setting. The ARC lost $400,000 per year funding from the Ministry of Science and Innovation for the ANZICE programme, and faces reorganisation of its other government funded programmes such as ANDRILL. We are also nearing the end of some major private donations. However, while there is some uncertainty, there are also opportunities. The landscape of Antarctic research funding is being reshaped by the development of the New Zealand Antarctic Research Institute (NZARI) - a public-private partnership with the goal of increasing investment in New Zealand Antarctic Research, and the re-organisation of the research sector into National Science Challenges. In 2012 we reached an agreement with the School of Geography, Environment and Earth Sciences (SGEES) to receive PBRF revenue for our graduate student thesis completions, which will generate significant revenue from 2013 onwards. Our staff submitted two fast-start and three standard Marsden grants in the 2013 round. You will see in this report that our research strategy continues to add quality and value to New Zealand's investment in Antarctica and climate change research, through a clear focus on understanding the impacts that our economy, society and environment may face in the future.

So finally, I would like to acknowledge the tremendous effort in 2012 of our staff, students and collaborators in creating an environment where, in the words of the late Professor Sir Paul Callaghan, "talent wants to live". I am thrilled to be leading this world-class research group that is nationally engaged and continues to deliver research vital to New Zealand's future.

Professor Tim Naish
Director, Antarctic Research Centre

LOOKING BACK TO THE FUTURE: OUR RESEARCH APPROACH

Scott's *Terra Nova* Hut, Evans Bay, Antarctica - Photo: Nick Golledge

Contents

The warming trend observed over the past century and models of its future trajectory suggest that we are rapidly heading towards a climate last experienced more than 3 million years ago.

In order to assess model-based climate projections, scientists are increasingly looking back to the future to gain insights into the likely response of Earth's climate. Ice sheets and oceans are some of the slowest responding elements of the climate system to an atmospheric CO_2 perturbation - taking centuries to millennia to play out, and are therefore potentially irreversible on human timescales. Paleoclimate reconstructions provide the only possible way to assess the long term "end-game" (equilibrium response), that we will commit our planet to this century based on the current warming scenarios - which virtually guarantee +2-3°C increase in global surface temperature.

This is why at the Antarctic Research Centre we focus on reconstructing the response of the Antarctic cryosphere and Southern Ocean to past climates that are similar to future projections and we study their influence on the global climate system, especially the Southwest Pacific region and New Zealand. Our research is leveraged by strong national and international collaborations and partnerships and world leading in-house polar drilling technology provided by the Science Drilling Office, which is funded and supported through a range of MBIE and Marsden programmes, Antarctica New Zealand and private donations. Our approach involves:

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

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

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

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

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.

UNEARTHING ANCIENT ICE SHEETS

Minna Bluff area, Antarctica - Photo: Nick Golledge

Firmly establishing the response of Antarctic ice sheets during sustained episodes of global warming in the geological past, are helping to 'ground truth' long-term projections of future ice sheet loss and their contribution to global sea-level rise.

The Centre's Antarctic geology group research both modern and ancient glacial and marine sedimentary systems on the margin of Antarctica and in the Southern Ocean in order to reconstruct changes in the behaviour of the ice sheet and its influence on global climate and sea-level. The following provides a selection of some recently published research highlights.

Ice Sheets Hate Water

The last time our planet experienced a prolonged period of atmospheric carbon dioxide (CO_2) concentration at ~400 ppm, the present day level, was in the Pliocene Epoch 3-5 million years ago and the world was 2°C warmer. This temperature increase now appears unavoidable by the end of the century. A reconstruction of Ross Sea temperature for the Pliocene from the ANDRILL 1B core, led by Rob McKay and published in the *Proceedings of the National Academies of Sciences* (McKay *et al.*, 2012), shows that the sea-surface was around 4°C warmer due to polar amplification – too warm for the existence of the marine-based West Antarctic Ice Sheet (WAIS). As renowned glaciologist Dr Bob Bindschadler often says "ice sheets hate water!" The international team's finding was based on the occurrence of a fossil assemblage of ocean surface algae (diatoms) that presently live in warmer subantarctic waters, and a new geochemical method for estimating temperature from fossilised organic molecules called lipids (TEX86). Rob's PhD student Molly Patterson is putting together a similar picture from a study of marine sediment cores recovered by the Integrated Ocean Drilling Program from the Wilkes Land margin of the East Antarctic Ice Sheet (EAIS) for the same time period. By analysing sediment properties, Molly is tracking regular episodes of iceberg calving confirming that the marine margins of the EAIS were also melting periodically and contributing to sea-level rise. Together these results validate an ice sheet model, that implies ice mass loss equivalent to +8 m of global sea-level rise from loss of the WAIS and the marine margins of the EAIS, and points to a threshold response of the Antarctic ice sheets at about 400 ppm CO_2 concentration. This could cause metres of global sea-level rise taking centuries to millennia to play-out, which we will likely be committed to by CO_2 emissions and warming in the next 100 years.

Ice Sheets and Sea-level Rise

Tim Naish and a team led by Ken Miller of Rutgers University, New Jersey, obtained a global sea-level estimate of ~20 m higher than present for the warmest periods of the Pliocene between 2.7 and 3.2 million years ago by compiling estimates from shallow-marine successions in Virginia (United States), Wanganui Basin (New Zealand), and Enewetak Atoll (north Pacific Ocean), and geochemical analyses of deep ocean sediment cores (Miller *et al.*, 2012). Their estimates published in *Geology* are consistent with information from ice sheet models and our geological data described above. They imply ice volume loss of Greenland (7 m Sea Level Rise (SLR)) and WAIS (4 m SLR), and some loss from the EAIS (3 m SLR). This new study helps to reconcile the longstanding controversy concerning the Pliocene stability of the EAIS (see below), and importantly for future sea-level rise, implies extreme sensitivity of both the Greenland ice sheet and marine portions of the Antarctic ice sheets to relatively small increases in atmospheric greenhouse gas levels and global mean surface temperature.

Reconciling Views on East Antarctic Ice Sheet Stability

A debate has raged in the scientific literature for the last 30 years since the publication of the first evidence for a greatly-reduced EAIS, by up to two-thirds, 3-5 million years ago based on the occurrence of glacial tills containing marine microfossil-bearing sediments preserved in outcrops high in the Transantarctic Mountains (TAM). The fossil diatoms were hypothesized to have originated in a large interior seaway where the EAIS presently lies, subsequently to be eroded by glaciers and uplifted in the TAM. The age and origin of the diatoms has been a point of contention. In a special issue of the *Philosophical Transactions of the Royal Society of Edinburgh*, Peter Barrett provides a new comprehensive assessment of the various lines of geological evidence from Antarctica. The paper reaches the conclusion that there is strong evidence for thinning and retreat around the margins, and within marine-based regions of the EAIS that may have contributed several metres of sea-level rise, but not tens of metres (Barrett, in press). Peter has followed and contributed to both sides of this debate over most of his research career.

Benchmark ANDRILL Publication

Six years after completion of drilling, a long-awaited collection of 15 papers published in the scientific journal *Global and Planetary Change* provides a comprehensive understanding of the age and depositional environments of the 12 million year sedimentary record recovered from beneath the McMurdo Ice Shelf (MIS) by the ANDRILL Program. The compilation, which represents the scientific results volume for the MIS Project, was led by Gary Wilson (University of Otago) and a team of guest editors including Tim Naish, Ross Powell (Northern Illinois University), Richard Levy and James Crampton (GNS Science) (Wilson *et al.* [eds.], 2012). The papers present a diverse array of key datasets and interpretations culminating in a synthesis of the tectonic and climatic evolution of the Western Ross Sea. ARC researchers co-authored five papers.

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UNLOCKING THE ICEHOUSE

A RICE ice core, Antarctica - Photo: Nancy Bertler

The Roosevelt Island Climate Evolution (RICE) Project aims to determine when and how quickly could the world's largest ice shelf, the Ross Ice Shelf, collapse allowing West Antarctic ice to accelerate into the ocean and exacerbate sea level rise.

The highlight for the ice core climatology group was the successful field season for the Roosevelt Island Climate Evolution (RICE) Project, a New Zealand led, nine nation collaboration with partners from Australia, Denmark, Germany, Italy, the People's Republic of China, Sweden, the United States of America, and the United Kingdom.

Frozen Diary of Things to Come

Antarctica and the Southern Ocean are warming. As a consequence, Antarctica is losing mass, largely from West Antarctica and the Antarctic Peninsula. One of the most dramatic responses to increasing temperature has been the recent catastrophic disintegration of ice shelves along the Antarctic Peninsula. While ice shelf collapse does not cause sea level to rise as ice shelves already float in the ocean, their loss accelerates the flow of the ice from the continent into the ocean, which does raise sea level. The potential for rapid deglaciation of West Antarctica remains a primary uncertainty in predictions for 21st century sea level rise. The recent and unpredicted collapse of multiple ice shelves and rapid acceleration of discharge of Antarctic ice suggests that dynamical responses to warming play a more significant role than is currently understood and captured in coupled climate-ice sheet models. Such models can be improved and validated by replicating known past changes.

The ANDRILL Program showed, that about 5 to 3 million years ago, the last time when atmospheric carbon dioxide (CO_2) concentration and temperatures were similar to those predicted for the end of the 21st century, the Ross Ice Shelf disintegrated multiple times, initiating the collapse of West Antarctica. However, no high resolution data exist from this time period to determine the rate of change. To improve our understanding on how quickly the Ross Ice Shelf could disintegrate, RICE aims to provide an annually resolved ice core record for the past 20,000 years and beyond, when global temperatures increased by 6°C to preindustrial temperatures, global sea level rose by ~120 m, and the Ross Ice Shelf grounding line retreated over 1,000 km. Most of the Ross Ice Shelf retreat occurred when global sea level had already reached modern levels. For this reason, the precise correlation between increasing air and ocean temperatures, and the velocity and characteristics of the ice shelf retreat, provides a unique opportunity to determine accurately the sensitivity of the Ross Ice Shelf to warming.

Drilling for Gold

During the 2012/13 field season, Nancy Bertler, RICE Chief Scientist, two of her PhD students, Daniel Emanuelsson and Peter Neff, and ARC Drilling Engineers, Alex Pyne and Darcy Mandeno, together with their international collaborators spent almost four months at Roosevelt Island, recovering the RICE ice core and reaching bedrock at 763 m depth on 20 December. The logistics of the project were supported by Antarctica New Zealand in collaboration with the US Polar Program. The camp, 760 km south east of Scott Base was supplied with 30 tonnes of drill system, fuel, drill fluid, scientific equipment and camping gear by Kenn Borek DC-3 and US Hercules aircrafts. Poor weather conditions at the site caused some of the flights to be delayed by more than three weeks. Nonetheless, the team completed the drilling ahead of schedule due to the superb performance of the new drill (see Science Drilling Office, p12).

A particular achievement is the high core quality, even through the brittle ice zone, where high pressure in the gas bubbles and thermal shock usually lead to heavily fractured ice. In addition, the team was able to retrieve small quantities of the underlying sediment, which could provide clues about the last time Roosevelt Island was under water.

In the field, the ice cores were stored 4 m underground in an actively cooled storage cave, keeping the ice well below minus 22°C, despite a particularly warm summer, causing at times positive surface temperatures. The cores were then transported in insulated boxes by DC-3 aircrafts, flying at 10,000 ft to keep the ice cold during the 2.5 hour long flight back to Scott Base. There Scott Base staff awaited the arrival of the cores with a refrigerated container, which was used to transfer the ice from the skiway to Scott Base. The ice was shipped aboard the US Supply Vessel, the *MV Ocean Giant*, back to New Zealand, arriving in March 2013.

Laboratories Running Hot

From May to mid-August, the international RICE community will meet in Wellington to process the ice at GNS Science's New Zealand Ice Core Research Laboratory, concluding with a RICE workshop on the emerging data. In preparation for the core processing GNS Science Ice Core Research Laboratory Technician, Rebecca Pyne, coordinated the cleaning of 60,000 vials for geochemical analyses. PhD students Peter and Andrea Tuohy will focus on trace element concentration, and Daniel on stable water isotope analysis.

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SECRETS FROM THE DEEP

Lake Ohau, New Zealand - Photo: Gavin Dunbar

Although the past is not an exact analogue for the future, our paleoclimate research provides insights into how the New Zealand region is likely to respond to projected global warming.

The marine and lake paleoclimate group investigate sediment cores from ocean and lake floors around the SW Pacific and New Zealand, spanning times when global climate was similar to or warmer than our present one.

New Zealand in a Warmer World

New Zealand is strongly influenced by the surrounding ocean as well as atmosphere. In turn, regional differences in ocean temperature often result from ocean currents redistributing warm and cool water around the Southwest Pacific.

During the last warm interglacial period, 125,000 years ago, global climate was warmer than today. In collaboration with scientists from New Zealand and overseas, Lionel Carter and Gavin Dunbar, identified the state of the marine environment at that time. Based on the distribution of tropical, temperate and polar species of plankton preserved in deep ocean cores from the SW Pacific, ocean temperatures and currents were reconstructed for this past warm phase.

Compared to today, results suggest the East Australian Current (EAC), which flows southwards off eastern Australia, was stronger than today. Thus there was likely an increase in the transport of warm water across the Tasman Sea especially off Tasmania. This accounts for greater warmth off the South Island. In contrast, the warm Tasman Front, and currents that pass around northern New Zealand, do not appear to have strengthened and in fact the ocean cooled slightly. These changes are linked to variations in westerly winds. Modern observations of the EAC reveal it strengthening and the waters off Tasmania are warming. This work is currently in review in the international journal *Paleoceanography*.

Another study (Ryan *et al.*, 2012) of fossil pollen from marine cores in the eastern Tasman Sea shows the nature of vegetation over the past 210,000 years. This work confirms the strong link between ocean and air temperature for most of New Zealand, with evidence for a rapid expansion of forest as oceans warmed.

Warming Ocean and Plankton Blooms

As the ocean off eastern South Island warmed during the last major interglacial phase, the base of the marine food chain switched from animal to plankton. Sediment cores from the Campbell Plateau show this switch occurred when waters were 1-2°C warmer than now. Indeed, satellites observe these algal blooms around early summer and there is evidence to suggest they are becoming more frequent. If the marine food chain switches, as shown by the core data, this raises questions regarding impacts on other marine organisms including commercial fish species. Results are under review in a *Deep-Sea Research* paper led by ARC student, Bella Duncan.

Enhancing the Forensic Arsenal

The recent development of chemical indicators of past environmental change has greatly improved identification of the structure and composition of the upper ocean – a critical zone where plankton are produced, atmospheric gases are taken up and released, and heat is stored and distributed. A PhD study by Julene Marr, based on laser ablation analysis of plankton shells, shows that trace elements can identify (i) temperatures through the upper ocean using the ratio of magnesium to calcium in plankton dwelling at different depths, (ii) water masses on the basis of temperature plus zinc and manganese contents, and (iii) key trace nutrients influence plankton blooms. The new indicators have been applied to a sediment core to reveal the ocean's response to changing currents and winds that accompanied the warming following the last ice age, 25,000 years ago.

Lake Ohau: A Detailed Archive of Recent Climate Change

Ice age glaciers retreated from Mackenzie Basin 17,000 years ago, to form Lake Ohau. This lake is slowly filling with layers of sediment to provide a record of environmental responses to the rapid warming from the last ice age to now. In collaboration with GNS Science, Gavin Dunbar and his PhD student, Heidi Roop, have been monitoring the modern lake to reveal the layers significance. During high rainfall the inflow of sediment-laden water to the lake increases. In the dryer winter period, sedimentation slows. Therefore the lake sediments are an archive of annual rainfall over thousands of years. A deep drill core record from Lake Ohau will help identify the South Island's response to climatic events such as El Niño - La Niña from the tropics and Southern Annular Mode from Antarctica. It will also reveal any affect of other climatic swings including the "little ice age" that chilled Western Europe in the 16th to 19th centuries.

Applying the Research to Modern Issues

Knowledge and expertise gained from research into modern and past ocean conditions is being applied to problems associated with modern climate change, especially in the field of natural hazards. A published study, led by Lionel Carter in *Geophysical Research Letters*, highlights the impact of severe storms on the abyssal ocean down to water depths exceeding 4200 m (Carter *et al.*, 2012). A record-breaking typhoon off Taiwan produced flood waters so laden with mud and debris that the river discharge sank into a submarine canyon and formed density flows that sped downslope at speeds exceeding 30 km/hr. These mud-laden flows ran over 200 km to transfer heat, carbon and nutrients to the deep ocean. In addition, the flows broke submarine fibre-optic cables that underpin the internet and international communications.

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CHANGING CLIMATE CHANGING ICE

Brewster Glacier, New Zealand - Photo: Huw Horgan

Glaciers are one of the clearest indicators of climate change, and ice sheets are increasingly viewed as vulnerable in a warming world.

The Antarctic Research Centre glaciology group study both modern processes on the Antarctic ice sheet and New Zealand mountain glaciers. They also use computer models to understand past climate and predict future response. The following highlights show the range of our expertise and provide a small taste of our current research.

Glacier Modelling to Understand Past Climate

Numerical glacier modelling provides a methodology for quantifying past climate change using moraine evidence. PhD student, Alice Doughty, led a paper in *Quaternary Science Reviews* that applied a model written by Brian Anderson, to the former Irishman Glacier in the Southern Alps of New Zealand (Doughty *et al.*, 2012). This location has been the focus of an intensive boulder-dating programme (Kaplan *et al.*, 2010 *Nature* 467, 194–197). Alice showed that the climate of the Antarctic Cold Reversal in New Zealand approximately 13,000 years ago, was 2 to 3°C colder than present, and that the glacial evidence was compatible with a nearby paleoclimate reconstruction based on fossil chironomids (non-biting midges) (Vandergoes *et al.*, 2008 *Quaternary Science Reviews* 27, 589-601). Broadly speaking, this work shows how ARC researchers are using glacier modelling as a means of reconstructing and understanding past climate. It also highlights an important collaboration between ARC staff, GNS scientists and colleagues at the University of Maine and Lamont-Doherty Earth Observatory of Columbia University, USA.

Climate Forcing of Ice Sheets

The Antarctic ice sheet is the largest single ice mass on Earth and its complete melting would raise global sea level by around 58 m. Many societally relevant questions remain unanswered concerning how this immense feature will respond to future warming. In September as part of this effort, Nick Golledge led a paper (Golledge *et al.*, 2012) in the prestigious journal *Proceedings of the National Academy of Sciences*. In this paper, he presented an ice-sheet modelling study of the Antarctic ice sheet at the Last Glacial Maximum, the peak in the last 'ice age' around 20,000 years ago. This new modelling study is one of the first to be directly constrained by geological evidence from this period, and the application of parallel computing allowed this model to be applied at a higher spatial resolution (5 km) than many previous efforts. The reward has been an improved understanding of how ice sheets respond to climate forcing.

Refining the Role of Wind Speed in Glacial Modelling

Local wind speed variations influence the energy and mass fluxes over snow by governing both, accumulation and ablation processes, and thus have a significant impact on snow cover and glacier evolution and thus for water resource availability. Ruzica Dadic, a visiting scientist from Switzerland, used model experiments to determine the sensitivity of turbulent fluxes to variations in wind speed under different climatic conditions (Dadic *et al.*, 2012). This work, published in *Advances in Water Resources*, shows the potential errors in energy balance modelling that are caused by incorrect estimates of wind speed. The paper further shows that those errors are largest in regions with high relative humidities, such as New Zealand, and highlights the importance of minimizing the errors in model input parameters, especially wind speed.

Antarctic Subglacial Lake Suitable for Drilling

Active subglacial lakes concentrate the distribution of water beneath ice sheets in both, space and time. Huw Horgan has led an effort, as part of the WISSARD (Whillans Ice Stream Subglacial Access Research Drilling) Project, to examine one of those active subglacial lakes beneath a fast flowing Antarctic ice stream, with the aim of determining a suitable location for subglacial drilling into an active lake. Seismic and surface observations from Subglacial Lake Whillans (SLW), West Antarctica, reveal that this active lake forms a persistent, albeit fluctuating, reservoir beneath Whillans Ice Stream. Their results further show a shallow water column (3-8 m) over a bed of soft sediment, that is suitable for drilling. The paper (Horgan *et al.*, 2012) was published in *Earth and Planetary Science Letters* and is the basis for the current drilling efforts (by WISSARD) into SLW, which would be the only other lake other than Lake Vostok, that has been accessed in Antarctica.

Understanding NZ's Mountain Climate

Andrew Makintosh and Drew Lorrey (NIWA) co-hosted a workshop "Understanding New Zealand's Mountain Climate" held at Victoria University of Wellington on 6-7 December. The workshop drew an audience of about 50 researchers who are undertaking studies of mountain climate, including representatives from Government, the hydroelectric industry, Department of Conservation and glacier guides. A focus of the workshop was centered on the importance of NIWA's high elevation climate station network. David Wratt (NIWA) gave the opening address, and it was followed by 17 presentations on New Zealand mountain climate and glaciers by scientists from New Zealand universities and Crown Research Institutes, particularly NIWA and the Antarctic Research Centre. The feedback about the workshop was very positive, and reinforced the importance of monitoring climate in the Southern Alps. The breadth of the research based on current observations underscores the importance of New Zealand's continued contributions to mountain climate science both nationally and internationally.

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University of New South Wales (Australia)
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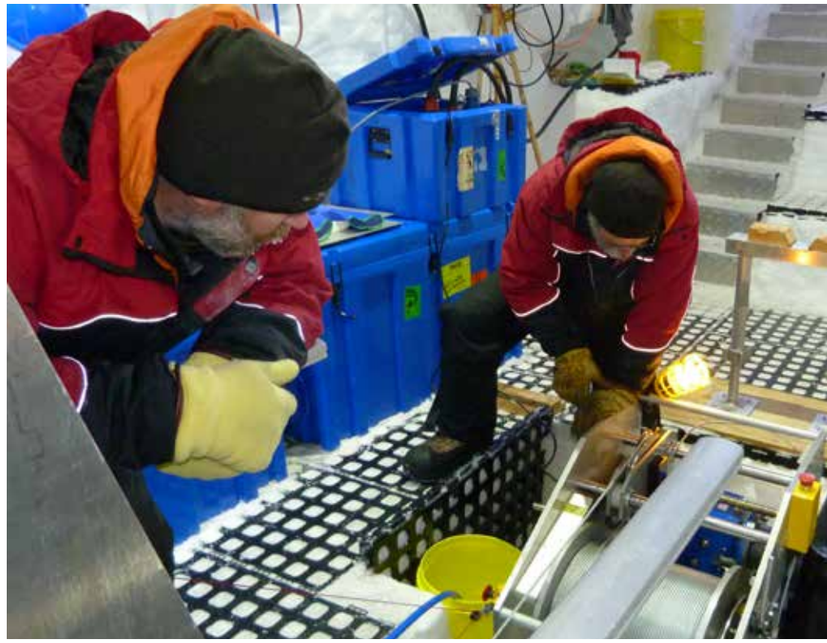
SCIENCE DRILLING OFFICE

Successful ice core drilling project on Antarctica's Roosevelt Island attributed to the drill technology designed by the Science Drilling Office duo.



Electrician, Hedley Berge and Alex Pyne, adjusting the winch, RICE, Antarctica
Photo: Nancy Bertler

The Science Drilling Office (SDO) is hosted in the Antarctic Research Centre and comprises Alex Pyne as the Projects Manager and Darcy Mandeno as the Operations and Field Engineer. The duo provide a technical focus and support for drilling related research undertaken by ARC members.

Setting the Scene

The main focus for the SDO in 2012 has been the continuation of ice coring at Roosevelt Island on the eastern side of the Ross Ice Shelf in Antarctica. In the 2011-12 summer season the coring operation infrastructure was set-up and the hole initially dry cored to 121 m depth, before enlarging the hole diameter and installing 54 m of fibreglass casing to conduct drill fluid past the permeable firn zone and keep the hole open for the following season. The borehole was then left in January 2012 with drill fluid ready for the completion of wet drilling in the 2012-13 field season. During that first season some improvement modifications to the drilling operations equipment were identified together with back-up option requirements that would increase our success for wet coring. These changes were undertaken during the year and included building another core barrel specifically for wet drilling made by Darcy at Pro Machining in Nelson. Other drill equipment parts and equipment for core processing were made by Steve Mawdesley and his team at the GNS Science workshop in Gracefield.

Technological Breakthrough

The wet coring drilling operation at Roosevelt Island was completed on 20 December after drilling for 27 days and reaching bedrock at a drill depth of 763 m. Six hundred and thirty four metres of ice core were recovered in very good condition even though brittle ice was encountered from about 300 m down. This very successful outcome continues to confirm that the Danish Hans-Tausen drill design, from which the Victoria University (VUW) ice core drill is based, is not only a very good intermediate drill design but that the new VUW design components, including the hydraulic drill mast designed by Darcy, have also proven their value.

The drill season at Roosevelt Island is now completed. However, poor January weather conditions at Roosevelt Island and limited aircraft availability reduced the amount of equipment that was recovered from site and this equipment recovery will be the focus for the 2013-14 field season.

Other SDO Activities

Alex continued his participation in the US Ice drill community as a member of the Ice Drilling Design & Operations (IDDO) Technical Advisory Panel and in the planning of the Deep Fault Drilling Project (DFDP) drilling on the Alpine Fault in New Zealand. Darcy has also been involved with design discussions with IDDO Engineers, Jay Johnston and Tanner Khul, who are tasked with the design of an US intermediate ice core drill also based on the Hans-Tausen Drill design.

In September 2013 Darcy and Alex expect to present results of the Roosevelt Island drilling and VUW intermediate drill design and performance at the 7th International Workshop on Ice Drilling Technology in Madison, Wisconsin, USA.

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The night shift team, led by Darcy Mandeno (right) operating the ice core drill, RICE, Antarctica - Photo: Nancy Bertler

MARSDEN MEDAL

The New Zealand Association of Scientists (NZAS) highest honour, the Marsden Medal was awarded to Lionel Carter for his oustanding contribution to science.

Lionel Carter with his wife Susan after receiving his Marsden Medal - Photo: Lionel Carter

As stated on the NZAS website, "The Marsden Medal is awarded for a lifetime of outstanding service to the cause or profession of science... in the widest connotation of the phrase."
The citation summarising Lionel's contribution recognises an outstanding 40 year research career as a practicing geoscientist making significant contributions to marine geology, palaeoceanography, and applied marine geology. Put quite simply our present knowledge of the undersea extent of the New Zealand continent and its interaction with water masses that originate in the Antarctic and tropical Pacific would not exist without Lionel's research career... which has transformed our knowledge of the interaction between climate, topography and ocean circulation with important implications for understanding the processes that have formed NZ's undersea exclusive economic zone.

Lionel Carter onboard the Tangaroa during one of his many research voyages - Photo: Lionel Carter

After completing a PhD at the University of British Columbia (Canada), he joined the NZ Oceanographic Institute (now NIWA) in 1973 where he spent the next 32 years as Project Director, Project Leader and Principal Scientist and participated on 35 oceanographic research voyages, 26 as voyage/science leader. He has been an invited scientist on five international voyages including Leg 181 of the Ocean Drilling Program. He has published over 130 refereed papers in international scientific journals, which have been cited more than 2000 times. Much of the research is applied to industry especially regarding the protection of the global subsea fibre-optic cable network that underpins international communications and the internet. During his career he has been a passionate educator and public communicator disseminating scientific results via the media, talks to the public and policymakers on the oceans and the impacts of climate change as well as popular articles. In 2003 he was made a Fellow of the Royal Society of New Zealand.

Since 2005, when Lionel joined the ARc as a Professor of Marine Geology at Victoria University, he has relished teaching in both the undergraduate and graduate programmes. He has supervised more than 24 postgraduate students, receiving in 2011 the Postgraduate Students Association Award for "Most Popular Supervisor" – an impressive feat given that most of his career was spent at a government research institute.

Although contemplating retirement, or at the very least more time with his wife Susan and widely dispersed family, Lionel remains dedicated to the cause. With colleagues and students he continues to publish insightful research on New Zealand's climate and oceans in a warmer world, and is a passionate advocate for New Zealand's world class climate and marine research community.

ALASKAN ADVENTURES

Andrew Mackintosh on Gulkana Glacier, Denali National Park, Alaska
Photo: Mike Hambrey (University of Aberystwyth)

The S.T. Lee Young Researcher Travel Award offers a fantastic opportunity for researchers to travel between the University of Alaska Fairbanks and Victoria University of Wellington.

This year two researchers from the Antarctic Research Centre headed to Alaska thanks to support from the S.T. Lee Travel Award. Andrew Mackintosh visited during June/July, where he met with glaciologists at the University of Alaska Fairbanks (UAF) and presented his research at the International Glaciological Society Conference "Glaciers and Ice Sheets in a Warming World". As part of the conference he also attended field trips to Denali National Park and Valdez in coastal Alaska. Andrew's highlights included visiting the 50 km-long surge-type glaciers descending off Mt McKinley, the Gulkana Glacier which is a long-term mass balance monitoring site, and the Columbia Glacier, a massive, fast flowing and rapidly retreating tidewater glacier in Prince William Sound.

Our other receipient, PhD student Alice Doughty, headed to Alaska in November, where she was greeted by temperatures of minus 32°C, less than 6 hrs of sunlight, pre day and the commonly asked question "Why would you go to Fairbanks in November?" Alice postponed her original scheduled trip in June in order to complete her PhD first. Also, being from Maine, USA, Alice really missed the snow (although the minus 32°C was a new record low for her). Alice also experienced the auroras (another first), saying:

"The Aurora was a single, bright green swath across the night sky. Almost unbelievable".

Alice presented her glacier modelling research to the Glaciers Group at UAF, and got some great feedback and follow-up conversations about the models used and potential future experiments. Her visit was hosted by Regine Hock and last year's S.T. Lee Award recipient, Marijke Habermann.

The aurora above Alice's hostel in Fairbanks, Alaska - Photo: Eiichi Matsuyama (Japan)

S.T. LEE LECTURE IN ANTARCTIC STUDIES

This year marked the 10th year of the S.T. Lee Lecture Series established by Singapore philanthropist Lee Seng Tee.

Therefore it was only fitting that a Chinese glaciologist and climatologist, Professor Qin Dahe, from the China Meteorology Administration, and State Key Laboratory of Cryospheric Sciences, Chinese Academy of Sciences presented "Linking Cryospheric Science in China and Antarctica" on 27 September.

Peter Barrett opened the event by giving a brief history of the Lecture and the previous presenters, before Vice-Chancellor Professor Pat Walsh's introduction. Professor Qin reviewed the progress of the current 5th Assessment of the Intergovernmental Panel on Climate Change, of which he is a member, and outlined changes to the global cryosphere. He also highlighted crysopheric science in Asia particularly the research on mapping permafrost and how this affected the construction of the Tibet highway and railway. He ended his presentation with an entertaining summary of his scientific expedition to Antarctica, where in December 1989 he became the first Chinese person to reach the South Pole on foot. He was part of a party of six scientists from China, Japan, France, United States, United Kingdom, and the former Soviet Union, who with the use of sled dogs ,traversed the entire Antarctic continent in seven months, collecting and analyzing samples along the way.

Qin Dahe making a point during his lecture in Victoria's Council Chambers
Photos: Image Services, VUW

The Series So Far

Antarctica and Climate Change in the Century Ahead - Causes, Consequences and Surprises - Inaugural Lecture
Professor Robert Dunbar - 8 August 2003

Antarctica's Contribution to Abrupt Global Warming Events - Past and Future
Professor James Kennett - 12 August 2004

How Sensitive is the Antarctic Ice Sheet to Climate Change? An Earth-Science Perspective
Professor David Sugden - 16 June 2005

The Exploration of Antarctic Subglacial Lakes: Science, Logistics and Politics
Professor Martin Siegert - 20 July 2006

The Ice Chronicles and Rapid Climate Change
Professor Paul Mayewski - 26 March 2007

Through a Crevasse Darkly: An Update on the Future of the Antarctic Ice Sheet
Professor Richard Alley - 20 May 2008

Antarctica and the Ice Age Puzzle
Professor George Denton - 15 May 2009

Waking Giants: Ice Sheets in a Warming World
Dr Robert Bindschadler - 19 May 2010

Lion Griefs in the Shade: Global Change Biology in the Antarctic
Professor Steven Chown - 8 September 2011

Linking Cryospheric Science in China and Antarctica
Professor Qin Dahe - 27 September 2012

RICHARD "DICK" BARWICK (1929-2012)

Dick Barwick, Colin Bull, Peter Webb and Barrie McKelvey in Antarctica as part of VUWAE 2, 1958-59 - Photo: Peter Webb

Dick was a young lecturer in biology at Victoria University specialising in lizards when he was seconded to the official summer support party of Sir Edmund Hillary's 1956-57 Trans-Antarctic Expedition. He returned the following summer as part of New Zealand's role in the Commonwealth Antarctic Research Programme where he met the two geology students of the first Victoria University of Wellington Antarctic Expedition (VUWAE 1), Peter Webb and Barrie McKelvey, helping facilitate opportunities for their explorations. The following year (1958-59) he joined with Peter, Barrie and the late physicist and expedition leader Colin Bull, for VUWAE 2 and its pioneering surveys of the McMurdo Dry Valleys, becoming the first people to explore and name much of the Victoria and Wright Valleys, of which Barwick Valley bears his name. This VUWAE expedition was vividly described 50 years later in Colin's book *Innocents in the Dry Valleys*.

Dick grew up in New Zealand with early boyhood memories of "free-wheeling yet self-disciplined roaming and exploring around the outskirts of Christchurch, with a particular interest in the birds, reptiles, amphibia and insects which inhabited that local universe." He was also a keen outdoorsman, skilled in art and photography, and established a career in biology with an MSc (Hons) at Victoria University on the ecology of scincid lizards. In 1960 Dick took up a lectureship in zoology at what was to become the Australian National University (ANU), Canberra. In the years that followed Dick pioneered animal satellite tracking and monitoring in Australia, and in the mid-1980s, began a long collaboration with Ken Campbell on the evolutionary anatomy and ecology of ~400-million year old Devonian lungfishes that brought them both widespread international recognition. He retired as Reader in Zoology at ANU in 1994. For more on Dick's life and career see www.anu.edu.au/emeritus/ohp/interviews/dick_barwick.html.

Dick Barwick, VUWAE 2 - Photo: Peter Webb

OUR FAR SOUTH

Enderby Island, Auckland Islands - Photo: Sarah Wilcox

In February, ARC's Lionel Carter and Dan Zwartz along with Rhian Salmon (SGEES) took part in the month-long voyage to the subantarctic islands and Antarctica led by well-known New Zealand economist and philanthropist Dr Gareth Morgan.

The voyage, under the banner *Our Far South*, aimed to raise New Zealanders' awareness of the area south of Stewart Island. The concept for the voyage was for a wide cross section of New Zealanders to visit the region, accompanied by experts in the fields of wildlife, oceanography, climate, history, conservation, fishing, and governance. They would then return to NZ and promote well-informed debate within their communities. The ship, *The Spirit of Enderby,* operated by Christchurch-based Heritage Expeditions, accommodated the fifty passengers (10 experts and 40 everyday New Zealanders) in modest comfort. Members of the Antarctic Research Centre, who had earlier collaborated with Gareth on his climate change book *Poles Apart*, were involved in developing the project over the past two years, and ARC staff Tim Naish and Rob McKay also contributed to subsequent activities that have included visits to schools, contribution to a science-based book *Ice, Mice and Men*, a raft of public and university lectures and the documentary film *Our Far South*. This was the ARC's second foray into Antarctic expedition cruises, after Peter Barrett and Dan Zwartz led a VUW study tour to the Antarctic Peninsula in 2006.

The vast region encompassed by *Our Far South* includes the subantarctic islands inside New Zealand's Exclusive Economic Zone extending down to latitude 56° South, the ocean region in the Ross Dependency south of 60°, and the Antarctic continent itself. For those who took part, it was a tremendous privilege to visit these remote places, with their unique and beautiful landscapes, wildlife and history. But the voyage had a serious purpose, and every day on board there were lectures and discussions covering the issues at stake. These issues are:

Climate change: How studies of the ice sheets and past climate in Antarctica can inform our understanding of future change and sea-level; How changes observed to be occurring in the Southern Ocean may be affecting endangered wildlife on the subantarctic islands.

Conservation: Learning about the record of endangered species in the region and the possible causes; The history and future possibilities of eradicating introduced pests from the subantarctic islands; Establishing the Million Dollar Mouse project to eradicate mice from Antipodes Island.

Antarctic governance and resources: Understanding the basis for New Zealand's position on the Antarctic Treaty and the regulation of mineral prospecting, fishing and tourism; Examining proposals for the management of the controversial toothfish fishery in the Ross Sea.

In all these issues, the aim of the expedition was not one of advocacy for particular positions or solution, but rather to encourage New Zealanders to debate these sometimes-neglected issues and to seek expert information when doing so. It continues the ARC's excellent record of outreach and science communication. For more information on *Our Far South* visit http://www.ourfarsouth.org/

(L-R) Lionel Carter and Gary Wilson (University of Otago); Dan Zwartz; Rhian Salmon - Photos: various

NZ ICEFEST

The ARC and GNS Science 'Knowledge Cubes' highlighting our collaborative research
Photo: Michelle Dow

The Antarctic Research Centre and Victoria University were a proud sponsor of and contributor to the inaugural NZ Icefest.

The month-long festival, held in Hagley Park, Christchurch from 14 September to 14 October celebrated New Zealand's relationship with Antarctica and our 100 year history as an Antarctic gateway. The Antarctic Research Centre had a number of staff and students involved in the various talks, debates and kids activities.

The festival opened with a '100 Years Dinner' a culinary display of Antarctica on a plate, followed by a drop of MacKinlay's Replica Edition of Shackleton's Whisky, recently found preserved in the ice. Victoria's talent was on display the following weekend beginning with the premier performance of *These Rough Notes* named for some of the last words written in Scott's diary on his fateful journey to the South Pole. Poems written by Bill Manhire were set to music by Norman Meehan, sung by Hannah Griffin and accompanied by musicians from the NZ School of Music. The weekend also featured the highly attended debate "What does climate change mean for us?" where experts, including VUW's Tim Naish (ARC), Dave Frame (CCRI), and Adrian Macey (School of Government), discussed the scientific, economic and political implications of climate change for New Zealand. Other events included the informal "Science Cafe's" where the public had the opportunity to talk with leading Antarctic researchers including Tim and Peter Barrett, and conversations with experts across various Antarctic themes involving Victoria's Dean of Science, David Bibby on the challenges of energy use in the Antarctic, and Bill on his Antarctic poetry. Also running throughout the festival were activities for the kids called "Science Stations". The ARC and GNS Science partnered up on *Flakes, Blobs, and Bubbles*. A concept created by ARC's Dan Zwartz and developed by Dan and PhD student Heidi Roop, kids of all ages learnt about the process of glacier and ice sheet formation. They were then tasked with drawing their version of snowflakes, firn and ice (with air bubbles) which were scanned and collated into an ice core mosaic on display during the festival. This activity also went global, being selected as the flagship educational activity for the Association of Polar Early Career Scientists Fall 2012 International Polar Week (see http//icecoreart.weebly.com/).

Tim Naish presenting the science during the climate change debate - Photo: Michelle Dow

Gondola Ridge, Mackay Glacier, Antarctica
Photo: Richard Jones

JARI AND NZARI

Antarctica New Zealand led the development of a new virtual institute, the New Zealand Antarctic Research Institute (NZARI) with the aims of increasing the quality, performance and profile of New Zealand's Antarctic research programme. NZARI'S Director, Gary Wilson from the University of Otago, has begun working with the research providers, stakeholders and funders to identify high priority research questions and programmes across the spectrum of Antarctic science. Peter Barrett has been asked to participate on an international advisory panel. The NZARI model is transformative as it will partner private funds, initially from the Robertson Foundation and Air New Zealand, with existing and new government funds to raise the Antarctic research capability and its relevance for New Zealand. Since the launch of the NZARI by New Zealand Prime Minister, Rt. Hon. John Key, in September at Premier House, the Joint Antarctic Research Institute (JARI) board members and its Director, Tim Naish, have been working with Gary to help support the development and implementation of NZARI goals. The JARI partners, GNS Science, VUW, NIWA, University of Otago and University of Canterbury, will continue to pool their resources and collaborate on climate and paleoclimate research within the NZARI framework.

IPCC REPORT

Antarctic Research Centre researchers, Tim Naish and Dan Zwartz, are both contributing to "Paleoclimate Archives" Chapter 5 of the Intergovernmental Panel on Climate Changes 5th Assessment Report due for release in early 2014. Tim, who is a Lead Author recently attended the 4th and final Lead Authors meeting held in Hobart in January. After working through more than 5000 expert reviewers comments on the chapter it is in very good shape and makes some strong statements about how the Earth system will respond to projected warming over coming centuries based on geological evidence from past warm climates. Of particular value is the potential contribution of the Antarctic ice sheet to sea-level rise and the insights from the greenhouse world. Victoria University has more authors contributing to the 5th Assessment Report than any other institute in the world (Tim Naish, Dan Zwartz, James Renwick, Dave Frame, Chris Hollis (ARC Adjunct) and David Wratt (CCRI Adjunct)

AWARDS AND APPOINTMENTS

Tim Naish — Appointed Deputy Pro Vice-Chancellor of the Faculties of Science, Engineering, Architecture & Design.

Andrew Mackintosh — Promoted to Associate Professor in the 2012 Academic Promotion Round.

Rob McKay — Appointed as a Lecturer in Sedimentology and Paleoceanography in February.

Huw Horgan — Appointed as a Lecturer in Geophysical Glaciology in May.

Lionel Carter — awarded the New Zealand Association of Scientists (NZAS) Marsden Medal in December.

Tim Naish— awarded a Victoria University "Public Contribution Award" for his outstanding contribution toward communicating and applying scholarly expertise to national and international communities.

Nancy Bertler — Appointed Co-Chair of the Scientific Committee on Antarctic Research (SCAR) AntClim21 Project.

Peter Barrett — Appointed Member of the International Science Advisory Panel for New Zealand Antarctic Research Institute (NZARI).

Rob McKay — Appointed Member of Australia New Zealand Implementation Committee for the Integrated Ocean Drilling Program.

Heidi Roop — chair to APECS (Association of Polar Early Career Scientists) Education and Outreach Committee.

Alice Doughty — Awarded Victoria University's John Gamble Prize in Geology.

Jesse Dimech — 1st Runner-up Poster Presentation at Geoscience Society of New Zealand Conference, Hamilton.

Joe Prebble — 2nd Runner-up Poster Presentation at Geoscience Society of New Zealand Conference, Hamilton.

Alice Doughty — 3rd prize for 'Best Student Poster' at Australasian Quaternary Association (AQUA) Meeting, Lake Tekapo.

ARC ENDOWED DEVELOPMENT FUND

The Victoria University Foundation now has almost $500,000 in the ARC Endowed Development Fund. This substantial fund enables us to give grants to students for conference travel, workshops or writing papers on their research. This year's recipients included Jane Chewings and Sanne Maas for writing-up papers on their Masters research, while Joe Prebble wrote up two papers, now submitted to *Marine Micropalaeontology*, on his PhD research. Lana Cohen's grant supported her attendance at the 32nd Scientific Committee on Antarctic Research (SCAR) Open Science Conference in Portland, Oregon in July. Lana presented a poster on her recent work on modelling stable isotopes in Antarctic snowfall. Matt Ryan attended the joint 13th International Palynological Congress and 9th International Organization of Palaeobotany Conference in Tokyo, Japan during August. Matt's talk discussed how Quaternary pollen preserved in marine sediments collected off the West Coast of New Zealand, were used to reconstruct past vegetation and paleoclimate of previous interglacial periods. Julene Marr attended the Urbino Paleoclimatology Summer School in Urbino, Italy in July and Shaun Eaves will head to Lamon-Doherty Earth Observatory at Columbia University, New York to undertake sample analysis.

TEACHING AND SUPERVISION

ESCI 301 fieldtrip, Whanganui - Photo: Dan Zwartz

Our staff support a significant proportion of the teaching being carried out in the paleoclimatology research theme within the School of Geography Environment and Earth Sciences.

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

Undergraduate Courses	
ESCI 111	Earth Systems & Global Change
ESCI 112	Fundamentals of Geology
ESCI 132	Antarctica: Unfreezing the Continent
ESCI 201	Climate Change and NZ's Future
ESCI 202	Sedimentology and Palaeontology
ESCI 204	Petrology and Microscopy
GEOG 220	Hydrology and Climate
ESCI 241	Introductory Field Geology
ESCI 301	Global Change: Earth Processes and History
GEOG 318	Quaternary Environmental Change
GEOG 323	Advanced Physical Environmental Processes

Graduate Courses	
ESCI 403	Stratigraphy and Palaeontology
ESCI 404	Special Topics
ESCI 412	Quaternary Geology
PGEO 401	Basin Anaylsis
PHYG 414	Climate Change: Lessons from the Past
PHYG 416	Special Topic B: General Circulation of the Atmosphere
PHYG 419	Natural Hazards & Risks: Processes and Impacts
PHYG 423	Field Geomorphology
ENVI 528	Climate Change Issues
PHYG 580	Research Preparation

Our teaching contribution also includes supervision of graduate students. In 2012 our staff supervised 15 PhD and 10 MSc students. The Antarctic Research Centre congratulates the following students who completed their theses in 2012:

Alice Doughty (PhD) *"Inferring past climate from moraine evidence using glacier modelling"*
Supervised by Andrew Mackintosh and Brian Anderson.

Joe Prebble (PhD) *"Terrestrial and ocean response to a Pleistocene warm interglacial as revealed by pollen and dinoflagellates from marine sediment cores, South Island, New Zealand"*
Supervised by Lionel Carter and Erica Crouch (GNS Science).

Bella Duncan (MSc) *"Environmental controls on coccolithophore blooms in the Southwest Pacific Ocean during Marine Isotope Stages 5e (125 ka) and 7a (210 ka)"*
Supervised by Gavin Dunbar and Lionel Carter.

Denise Fernandez (MSc) *"Do winds control the confluence of subtropical and subantarctic surface waters east of New Zealand?"*
Supervised by Lionel Carter and Melissa Bowen (now University of Auckland).

Georgia Grant (MSc) *"Pliocene-Pleistocene orbital cyclostratigraphy and glacial evolution of the East Antarctic Ice Sheet from continental rise IODP site U1361, Wilkes Land margin, East Antarctica"*
Supervised by Tim Naish and Rob McKay.

Kylie Christiansen (MSc) *"Paleo-oceanographic and -climatic reconstruction in the southwest Pacific [ODP Site 1123] during MIS 11"*
Supervised by Lionel Carter and Joel Baker (SGEES)

Laura Kehrl (MSc) *"Glacier speed-up events and subglacial hydrology on the lower Franz Josef Glacier, New Zealand"*
Supervised by Andrew Mackintosh and Huw Horgan.

Sanne Maas (MSc) *"Last Glacial Maximum – Holocene glacial and depositional history from sediment cores at Coulman High, beneath the Ross Ice Shelf, Antarctica"*. Supervised by Tim Naish and Rob McKay.

OUTREACH

Heidi Roop helps 2 yr old Ava Vandergoes draw a snowflake, NZ Icefest
Photo: Michelle Dow

Our staff and students were involved in a variety of outreach activities during the year. These activities include media interviews, public talks, and school visits, allowing us to present our research and knowledge to the wider community both here and overseas.

Media Interviews

Hutt News: "$200,000 prize won" Rob McKay, 3 January.

National Radio: "RICE" Nancy Bertler and Kate Sinclair (then GNS Science), 4 January.

The Wellingtonian: "Science winner to share wealth" Rob McKay, 19 January.

Nature 481: "Turning Point: Rob McKay", 26 January.

Radio Zealand 'Our Changing World': "Nelson's boulder bank" Warren Dickinson, 26 January.

Radio New Zealand 'Our Changing World': "Iconic glaciers" Brian Anderson and Andrew Mackintosh, 2 February.

National Business Review: "Victoria researcher wins top science prize" Rob McKay, 9 February.

National Radio 'Nine till Noon': "Global sea-level rise" Tim Naish, 22 March.

Dominion Post: "Sea-level rise for New Zealand" Tim Naish, 24 March.

Canterbury Student Radio 'Spanky': "Sea-level rise" Tim Naish, 27 March.

Radio New Zealand 'Our Changing World': "The Antarctic RICE Project" Nancy Bertler, 12 July.

The Antarctic Sun: " Island Time-Scientists pursue paleoclimate, deglaciation records from atop Roosevelt ice dome" Nancy Bertler, 13 July.

The Nelson Mail: "How and why we believe" Tim Naish, 28 July.

Radio New Zealand 'Checkpoint': "Antarctica once had a climate like Queensland" Rob McKay, 3 August.

RadioLive 'Weekend Variety Wireless': "Tropical Antarctica" Rob McKay, 2 September.

Listener: "Global climate change-sea-level rise" Tim Naish, 17 September.

TV3 Firstline: "Arctic sea-ice loss" Tim Naish, 21 September.

TV3 News: "Antarctic and Arctic climate change" Tim Naish, 23 September.

The Press: "Thousands turn out ice core art" Heidi Roop and Victoria University, 15 October.

Listener: "Ice cores clues to past climate" feature by Rebecca Priestley, 20 October.

Radio New Zealand 'Checkpoint': "Scientists drill crucial ice core in Antarctica" Nancy Bertler, 21 December.

TV3 News: "Kiwi Antarctic breakthrough offers view back in time" Nancy Bertler and Tim Naish, 23 December.

Public Talks, School Visits & Events

Ridgway School Visit: Dan Zwartz, 3 February.

'Our Far South' Expedition to Antarctica: "The greatest flows on Earth" Lionel Carter, 9 February-10 March.

'Our Far South' Expedition to Antarctica: "New Zealand, Southern Ocean and Antarctica" Lionel Carter, 9 February-10 March.

'Our Far South' Expedition to Antarctica: "About the Southern Ocean – shaping climate and ocean" Lionel Carter and Rob Murdoch (NIWA), 9 February-10 March.

Korokoro School Visit: Tim Naish, James Crampton (GNS Science) and Sanne Maas, 28 February.

Gifted Kids Programme, Victoria University: Gavin Dunbar, Cliff Atkins (SGEES), Alice Doughty and Sanne Maas, 29 February and 2 March.

Robert Harris Oration, 21st Convocation of the Royal Australasian College of Dental Surgeons, Queenstown: "Climate Change" Tim Naish, 1 April.

'Our Far South Expedition' Public Talk: "Taking Antarctica's Pulse" Tim Naish, 2 May.

Australian Academy of Science '100 years of Australian Antarctic Science' Symposium: Tim Naish, 4 May.

NZCCC Sea-level Rise Conference: Tim Naish (Convenor and MC for panel discussion), 11 May.

Queen Margaret College Visit: Heidi Roop, 21 May.

The Navy League 'Shaping New Zealand's Oceans Policy' Conference: "Southern Ocean" Lionel Carter, 24 May.

Alumni Talks: "9 billion people, global warming, polar ice sheets and climate change" Tim Naish, 19 June (Kuala Lumpur), 20 June (Kuching), 21 June (Singapore).

'Our Far South' Lunchtime Seminar: "Climate changes in Our Far South" Rob McKay and Lionel Carter, 11 July.

'Our Far South Expedition' Public Talk: "Science and Our Far South" Lionel Carter, 16 July.

Public Lecture, Nelson: "9 Billion People, climate change and sea-level rise" Tim Naish, 1 August.

Victoria University Alumni Function: "Antarctica in a Warmer World: Insights from the Past" Rob McKay, 22 August.

University of Technology, Malaysia Delagation Visit: Tim Naish, 6 September.

NZ IceFest 'MBIE Big Issues: Climate Change, What it Means for New Zealand': Presentation and panel discussion, Tim Naish, 22 September.

NZ IceFest 'UC Science Cafe: Climate Change: Up Close and Uncomfortable': Tim Naish and Peter Barrett, 23 September.

NZ Icefest 'Scool Quiz': Heidi Roop, Peter Neff and Richard Jones, 25 September.

NZ IceFest 'Science Station: Flakes, Blobs and Bubbles': Dan Zwartz, Heidi Roop, Michelle Dow, Peter Neff, Richard Jones, Mike Hannah (SGEES), Jane Chewings, Warren Dickinson, and Cliff Atkins (SGEES), 14 September-6 October.

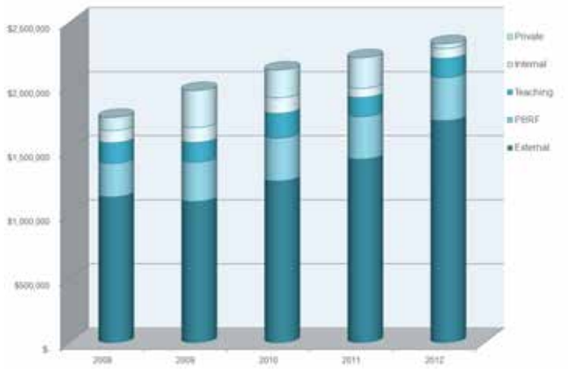
Antarctica Day: Heidi Roop (coordinator), 1 December.

AGU Exploration Station: Heidi Roop, 2 December.

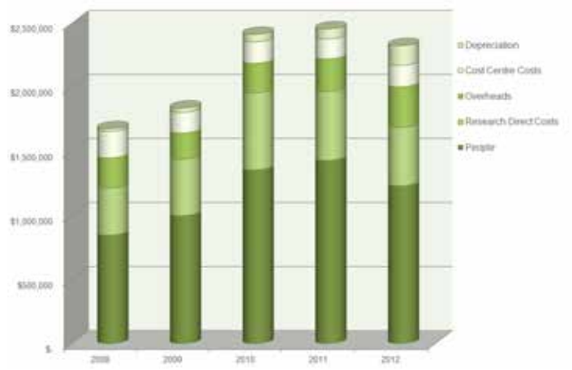
FINANCIAL SUMMARY

Nansen Ice Sheet, Antarctica - Photo: Gavin Dunbar

The Antarctic Research Centre has continued to grow over the last five years, under the Directorship of Tim Naish. While our overall revenue has increased each year, new funding will be required to continue to support our expenditure costs.



2008-2012 Revenue Summary



2008-2012 Expenditure Summary

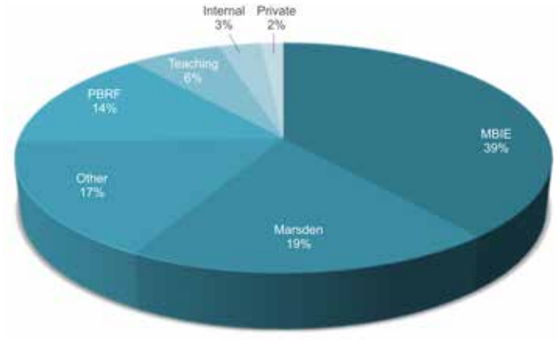
A five year summary of our revenue sources shows the proportions of revenue the ARC receives from various funding sources; External, PBRF, Teaching, Internal and Private. External sources include funding from MBIE, Marsden, and other national and international organisations. PBRF is calculated by VUW based on external research funding that meets PBRF criteria and the quality rating of our staff. Teaching is the contribution from SGEES for teaching provided by ARC Staff and is calculated on hours. Internal funding is provided by University supported grants, and Private revenue are the Private Donations held by the VUW Foundation. The overall increase in revenue over the five year period is primarily a result of increased external revenue, whereas PBRF, Teaching and internal funding have remained relatively constant. Our private donations funding significantly decreased in 2012 as existing funds are nearly spent, with no additional donations yet received.

Our expenditure over the same five-year period has also been steadily increasing. In 2008 we had 12 academic and general staff, by the end of 2012 we had 17. This directly affects the costs spent on not only salary related expenses but also our cost centre expenditure on IT (computers and phones) for staff. The decrease in the People costs in 2012 was a result of two of our academic staff being supported directly by the Research Office for six months. Whereas, the significant increase in the depreciation of capital items in 2012 was due to the full capitalisation of our $1M Ice Core Drill and its modifications and the purchase of new Seismic equipment.

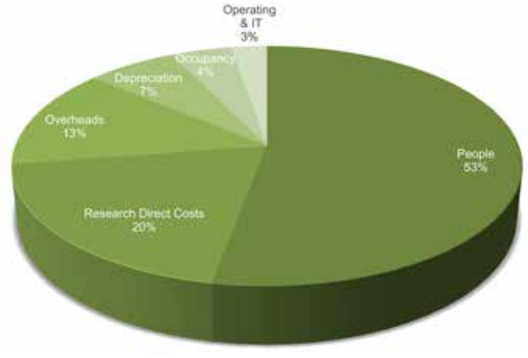
2012 Finances

The Antarctic Research Centre finances include both a cost centre budget and grant funds held by the Research Trust. In 2012, the ARC received a total of $2.33M in revenue and had a corresponding expenditure also of $2.33M. Although the cost centre budget recorded a $65K loss the research funding contribution to the University via overheads from Research Trust grants was $316K, thus overall the ARC contributed $251K to the University.

The ARC actual revenue and expenditure for 2012 are summarized in the charts below (all figures are exclusive of GST), these figures combine the cost centre budget that operates over the VUW financial year (January-December) and Research Trust grant budgets which operate over the life of the projects. As such, the year end balances for revenue versus expenditure in Research Trust grants are often out-of-phase.



2012 Revenue Sources



2012 Expenditure

Revenue Sources

In 2012, the Antarctic Research Centre received revenue from MBIE, Marsden, Other, PBRF, Teaching, Internal, and Private. The highest proportion of funding came from MBIE funding either directly or through sub-contracts from GNS Science and NIWA. The Other grants include a Rutherford Fellowship grant and the Prime Minister Emerging Scientist fund, as well as receiving funding from other international organisations.

Expenditure

Just over half of the expenditure is related to staff and research assistant costs including salaries, annual leave, and superannuation. The Research Direct Costs include expenditure directly associated with research projects such as field work costs, conference attendance, analyses, and consumables. The other major expenditure is the Research Office and University Overheads which are transferred out of Research Trust grants by the University for administrative purposes and to cover services provided by the Research Office and central University. The remaining expenditure relates to the depreciation of CAPEX equipment which was, as stated earlier, significantly higher in 2012 due to the full capitalisation of the Ice Core Drill and its recent modifications and the acquistion of Seismic equipment being shared with SGEES, and the general operating costs of the cost centre including office space, computers, phones and costs associated with the daily running of the Centre such as printing, catering, and postage.

New Funding Success

Nick Golledge was awarded an emerging researchers Marsden Fast-Start grant for his research “Will the East Antarctic Ice Sheet contribute to global sea-level rise under warmer- world scenarios?” He will receive $345,000 over three years.

Huw Horgan was awarded a University Research Establishment grant of $9,780 for his research project “Estimating and observing the dynamic response of Tasman Glacier”. This will support field work on the Tasman Glacier in 2013.

PUBLICATIONS

Peer-Reviewed Publications (37)

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Books

Wilson, G.S., **Naish**, T.R., Powell, R.D., Levy, R.H., Crampton, J.S., (eds.) (2012). Late Neogene chronostratigraphy and depositional environments on the Antarctic margin: New insights from the ANDRILL McMurdo Ice Shelf Project. *Global and Planetary Change* 96-97: 1-204.

Reports

Field, B.D. and **Atkins**, C.B., (2012). Characterization of fine-grained sediment in the AND-2A drillhole core using QEMSCAN©. GNS Science Report 2012/42, 7p+appendices. ISBN 978-1-972192-30-6.

CONFERENCES

Session/Theme Convenor

Bertler, N.A.N., (2012). Climate of the Holocene. International Partnerships in Ice Core Sciences - *First Open Science Conference*, Presqu'ile de Giens, Côte d'Azur, France, 1-5 October 2012. (Convenor)

Invited Presentations

Barrett, P.J., (2012). Antarctica and the global climate system - a Deep Time perspective. *Antarctic Climate Evolution Symposium SCAR Open Science Meeting*, Portland, Oregon, USA. 16-19 July 2012. (Plenary)

Carter, L., (2012). Anatomy of the Christchurch earthquake – lessons for society, industry and science. *International Cable Protection Committee Plenary,* Lisbon, Portugal, 16-19 April 2012.

Dadic, R., (2012). Wind-driven mass balance processes over snow and ice. *University of Otago Physics Colloquium*, Dunedin, New Zealand, 17 September 2012.

McKay, R., (2012). A university-based perspective on early career pathways in science. *New Zealand Association of Scientists 2012 Conference*, Wellington, New Zealand, 16 April 2012.

Naish, T., (2012). Palaeoenvironmental records from Antarctica. *The Australian Academy of Sciences Symposium - 100 years of Antarctic Science*, Canberra, Australia, 4 May 2012. (Keynote)

Naish, T., (2012). How geological records inform us on future climate change. *34th International Geological Congress,* Brisbane, Australia, 5-10 August 2012. (Plenary)

Naish, T., (2012). Antarctic Plio-Pleistocene Climate Evolution. *SCAR Open Sciences Conference*, Portland, USA, 16-19 July 2012. (Keynote)

Naish, T., (2012). Paleoclimate perspectives on polar ice sheet and sea-level sensitivity to global warming. *2nd Australian Earth System Outlook Conference*, Canberra, Australia, 26-27 November 2012. (Keynote)

Naish, T., **McKay**, R., **Carter**, L., Riesselman, C., Sjunneskog, C., Winter, D., Dunbar, R., Sangiorgi, C., Warren, C., Pagani, M., Wilmott, V., Levy, R., Powell, R., DeConto, R., (2012). Antarctic and Southern Ocean influences on Late Pliocene global cooling. *European Geosciencs Union General Asssembly*, Vienna, Austria, 22-27 April 2012.

Roop, H., (2012). Early career scientists tackling polar outreach: Using the APECS network to connect the polar regions with communities around the world. *34th International Geological Congress,* Brisbane, Australia, 5-10 August 2012.

Oral Presentations

Anderson, B. and **Mackintosh,** A., (2012). What caused the late 20th century advance of New Zealand glaciers? *New Zealand Snow and Ice Research Group (SIRG) Annual Workshop*, Twizel, New Zealand, 13-15 February 2012.

Anderson, B.M., **Mackintosh**, A.N., Hreinsson, E., Sood, A., Zammit, C., Hendrikx, J., Clark, M., (2012). Retreat of lake-calving, debris-covered glaciers: Hydrological implications. *New Zealand Snow and Ice Research Group (SIRG) Annual Workshop*, Twizel, New Zealand, 13-15 February 2012.

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Atkins, C.B., **Dunbar**, G.B., **Zwartz**, D.P., **Chewings**, J.M. **Golledge**, N.R., (2012). Aeolian sediment distribution studies in the SW Ross Sea, Antarctica. *Annual Antarctica New Zealand Conference - Looking to the Future*, Christchurch, New Zealand, 4-5 October 2012.

Barrett, P.J., Cramer, B., Miller, K., Wright, J., (2012). Earth's temperature on geological time scales. *34th International Geological Congress,* Brisbane, Australia, 5-10 August 2012.

Bertler, N., Mayewski, P., and **Carter**, L., (2012). Cold conditions in Antarctica during the Little Ice Age — implications for abrupt climate change mechanisms. *34th International Geological Congress,* Brisbane, Australia, 5-10 August 2012.

Bostock, H.C., Armand, L.K., Barrows, T.T., **Carter**, L., Chase, Z., Cortese, G., **Dunbar**, G.B., Ellwood, M., Hayward, B., Howard, W., Neil, H.L., Noble, T.L., Moss, P.T. Moy, A.D., Williams, M.J.M., (2012). A review of the Australian-New Zealand sector of the Southern Ocean over the last 30 ka. *Australasian Quaternary Association (AQUA) Meeting*, Lake Tekapo, New Zealand, 12-17 February 2012.

Carter, L., (2012). Southern Ocean change and New Zealand. *Navy League of New Zealand Oceans Policy Conference,* Wellington, New Zealand, 24 May 2012.

Carter, L., (2012). Marine environmental report. *International Cable Protection Committee Plenary,* Virginia Beach, USA, 8-10 October 2012.

Carter, L., (2012). Frequent earthquake- and weather-forced sediment gravity flows - evidence from subsea cable breaks off Taiwan. *Virginia Institute of Marine Sciences*, Virginia, USA, 12 October 2012.

Carter, L., **Fernandez**, D., and Bowen, M., (2012). Past migration of ocean fronts in the SW Pacific; insights from modern observations. *International Geological Congress*, Brisbane, Australia, 6-10 August 2012.

Carter, L., (2012). In a state of flux. *NZ Association of Scientists Annual Awards*, Wellington, New Zealand, 27 November 2012.

Carter, L., (2012). Southern Ocean in a warming world. *Postgraduate Certificate in Antarctic Studies (PCAS) Programme*, Christchurch, New Zealand, 5 December 2012.

Chewings, J., **Atkins**, C.B., **Dunbar**, G.B., **Golledge**, N.R., (2012). Aeolian sediment distribution in McMurdo Sound, Antarctica. *Annual Antarctica New Zealand Conference - Looking to the Future*, Christchurch, New Zealand, 4-5 October 2012.

Chinn, T. J. and **Anderson**, B., (2012). Unhinged at the snowline - a simplified approach towards understanding AAR values. *New Zealand Snow and Ice Research Group (SIRG) Annual Workshop*, Twizel, New Zealand, 13-15 February 2012.

Cortese, G., **Carter**, L., **Dunbar** , G., and Group 5e, (2012). SW Pacific Ocean response to a warmer climate – lessons from the last interglacial. *Geoscience Society of New Zealand Conference*, Hamilton, New Zealand, 25-28 November 2012.

Cortese, G., **Dunbar**, G., Scott, G., **Carter**, L., Bowen, M., Crundwell, M., Bostock, H., Neil, H., Hayward, B., Sabaa, A., Martinez, I., Sturm, A., (2012). Southwest Pacific Ocean response to a warmer world - what happened during Marine Isotope Stage 5e? *34th International Geological Congress,* Brisbane, Australia, 5-10 August 2012.

Dadic, R., Light, B., Brandt, R., Schneebeli, M., Carns, R., Mullen, P., Fitzpatrick, M., Warren, S.G., (2012). Albedo processes on the snowball ocean. *2nd NZ Sea Ice Symposium*, Wellington, New Zealand, 21-22 February 2012.

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Golledge, N. and Levy, R., (2012). Ice dynamics in the Trans-Antarctic Mountains. *Transantarctic Mountains (TAM) Camp Workshop*, Indianapolis, USA, 25-27 June 2012.

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Mackintosh, A., (2012). What caused the late 20th century advance of New Zealand Glaciers? *International Glaciological Society (IGS) Symposium*, Fairbanks, Alaska, 24-29 June 2012.

Marr, J.P., **Carter**, L., Bostock, H.C., Handler, M., Bolton, A., (2012). Tracing water masses in the SW Pacific Ocean. *Urbino Summer School in Paleoclimatology*, Urbino, Italy, 11-31 July 2012.

Marr, J.P., **Carter**, L., Bostock, H.C., Handler, M., Bolton, A., (2012). Southwest Pacific Ocean response to a warming world using Mg/Ca, Mn/Ca and Zn/Ca to track the surface ocean water masses, *Australian Marine Sciences Association (AMSA) and New Zealand Marine Sciences Society (NZMSS) Conference*, Hobart, Australia, 1-5 July 2012.

McKay, R., (2012). Antarctic and Southern Ocean influences on Late Pliocene global cooling. *Annual Antarctica New Zealand Conference - Looking to the Future*, Christchurch, New Zealand, 4-5 October 2012.

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Pressure ridge, near Barne Glacier, McMurdo Sound, Antarctica
Photo: Nick Golledge

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