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

Antarctic Research Centre

Annual Review 2010

Contents

Director's Summary

As I reflect on 2010, it gives me great pleasure to see the quality and breadth of science being achieved by ARC staff and students, especially after several years of building up capacity. In this review you will see our staff and students have been heavily engaged in field activities including participation on the Integrated Ocean Drilling Program expedition to the Wilkes Land margin of Antarctica, glaciological studies in the Southern Alps of New Zealand and the Transantarctic Mountains, the highly successful site surveys on the Ross Ice Shelf for the ANDRILL Coulman High Project, participation in the Greenland NEEM ice drilling programme, and final site preparations for ice core drilling on Roosevelt Island by the RICE Project. ARC staff and students led delivery of new science results at several major international meetings (International Polar Year Oslo Meeting, Scientific Committee on Antarctic Research Open Sciences Meeting, Fall American Geophysical Union Meeting, Australian Earth Sciences Meeting). While results continue to be published in international journals, emphasis this year has gone into writing and submitting papers. ANDRILL, ANZICE, and the glacial modelling programmes have a number of high profile papers in review or accepted in journals such as *Nature*, *Nature Geoscience*, *Science*, *Journal of Geophysical Research*. The publication highlights this year have largely come from the glaciology and modelling group, which is now really hitting its straps after building capacity over several years. The Science Drilling Office has had another busy year preparing and presenting to international partners a programme plan and budget for the ANDRILL Coulman High Project, co-ordinating site surveys for Coulman High and completing and testing the new intermediate depth ice drill for the RICE project.

More than 30 Antarctic researchers including one of our own departed from Wellington in January for the Wilkes Land drilling expedition. While the *JOIDES Resolution* was moored in Wellington in early January, GNS Science and the ARC hosted a series of events, including ship tours for invited guests, a media briefing on board, public lectures and a seven-day holiday programme. ARC staff were also fortunate to go on board both the German Research Vessel *Polarstern* and the Korean Icebreaker *Aaron* when they visited Wellington during 2010. In January, the ARC hosted a workshop which brought together Antarctic researchers from around New Zealand with funders and stakeholders and their American counterparts. The one-day workshop fed into a larger Joint Commission Meeting held the following day. The meeting was organised by the Ministry of Research Science and Technology (MoRST) and US Department of State to promote closer collaboration between US and New Zealand research organisations. Distinguished NASA scientist, Dr Robert Bindschadler presented the 2010 S.T. Lee Lecture in Antarctic Studies titled *"Waking Giants: Ice Sheets in a Warming World"*. ARC researcher Nick Golledge travelled to the International Arctic Research Center, University of Alaska-Fairbanks as the recipient of the 2010 S.T. Lee Young Researcher Award, where he is collaborating with developers of the Parallel Ice Sheet Model and applying it to the Southern Alps and Antarctica.

By year end we had 18 staff and 28 graduate students. Our 2010 operating budget was $2.13M. FRST, Marsden and other external funding comprises 59% of the Centre's revenue with PBRF, internal funding and revenue from teaching making up another 31%. Revenue from private donations has been declining and presently accounts for 10% of our revenue. Our expenditure is dominated by staff salaries (56%), 25% goes to research direct costs, and the remainder to overhead and operating expenses.

We continue to build on our close relationships with Antarctica New Zealand and other New Zealand research partners through the Joint Antarctic Research Institute to undertake large research initiatives in a more coordinated and efficient way. Together we are maintaining a world class Antarctic paleoclimate research capability in New Zealand.

Professor Tim Naish, Director
Antarctic Research Centre

Our mission is to improve understanding of Antarctic climate history and processes and their influence on the global climate system, especially on New Zealand and the southwest Pacific region. This is needed to provide a sound basis for national and international policy development on global change issues. The field also provides exciting opportunities and challenges for young researchers.

Antarctic Research Centre Advisory Board

The Antarctic Research Centre Advisory Board meet twice yearly, with 2010 meetings in February and October. The members of the 2010 board are listed below:

Board Members

David Bibby (convener), Dean of Science, Victoria University of Wellington
Ian Graham, General Manager-Research, GNS Science
Mike Hannah, Head of School of Geography, Environment and Earth Sciences
Trevor Hughes, Antarctic Policy Unit, Ministry of Foreign Affairs & Trade
Wendy Lawson, Gateway Antarctica representative, University of Canterbury
Alex Malahoff, CEO, GNS Science
Ian McIntosh, Manager, Research & Commercial, Victoria University of Wellington
Rob Murdoch, Research Manager, NIWA
Tony Robinson, MoRST representative
Lou Sanson, CEO, Antarctica New Zealand

Antarctic Research Centre People

The Antarctic Research Centre was set up in the early 1970's, centering its research in the field of earth sciences. The staff, associated researchers, adjuncts, and students of the ARC, along with their main research interests, are listed below:

Staff

Tim Naish, Professor and Director (0.8 FTE)	Sedimentology and paleoclimatology
Brian Anderson, Research Fellow (0.67)	Glacial modelling
Peter Barrett, Professor of Geology (0.5)	Stratigraphy and Antarctic climate history
Nancy Bertler, Senior Research Fellow (0.5)	Ice core climatology
Melissa Bowen, Senior Research Fellow (0.2)	Physical oceanography
Lionel Carter, Professor in Marine Geology (0.7)	Marine geology
Ruzica Dadic, Visiting Research Fellow (1.0)	Snow and ice processes
Warren Dickinson, Senior Research Fellow (0.2)	Sedimentary petrology and permafrost
Michelle Dow, Administrator (0.8)	Paleontology and climate change
Gavin Dunbar, Senior Research Fellow (1.0)	Marine geology
Tamsin Falconer, Centre Manager (1.0)	Sea ice, drilling, Antarctic history and art
Nick Golledge, Post-Doctoral Fellow (1.0)	Glacial modelling and paleoclimatology
Catherine Hines, Administrator (0.8)	Art
Huw Horgan, Research Fellow (1.0)	Ice sheet dynamics
Andrew Mackintosh, Senior Lecturer (0.5)	Glacial geology and glacial modelling
Darcy Mandeno, Operations & Field Engineer (1.0)	Antarctic drilling
Rob McKay, Post-Doctoral Fellow (1.0)	Sedimentology
Alex Pyne, Projects Manager (1.0)	Antarctic logistics and drilling technology
Dan Zwartz, Research Fellow (1.0)	Antarctic ice sheets and sea-level

Associated Researchers

Cliff Atkins, Lecturer in Geology	Sedimentary processes and environments
Joel Baker, Professor of Geochemistry	Paleoceanography and paleoclimatology
Mike Hannah, Associate Professor in Geology	Marine palynology and biostratigraphy
Simon Lamb, Associate Professor	Science communication

Adjuncts

Helen Bostock, Adjunct Research Associate	Paleoceanography and geochemistry
James Crampton, Adjunct Professor	Paleontology
Robert De Conto, Adjunct Professor	Earth systems modelling and paleoclimatology
Robert Dunbar, Adjunct Professor	Climate dynamics and oceanography
Stuart Henrys, Adjunct Professor	Structural geology and seismic stratigraphy
Chris Hollis, Adjunct Professor	Micropaleontology
Richard Levy, Adjunct Associate Professor	Micropaleontology and biostratigraphy
Dave Lowe, Adjunct Professor	Atmospheric chemistry
Barrie McKelvey, Adjunct Professor	Antarctic ice sheet history
Helen Neil, Adjunct Associate Professor	Oceanography and geochemistry
Alan Orpin, Adjunct Research Associate	Marine geology
Ross Powell, Adjunct Professor	Sedimentology and climate change
Alexandra Thompson, Adjunct Research Associate	Atmospheric chemistry
Peter Webb, Adjunct Professor	Micropaleontology and biostratigraphy
Mike Williams, Adjunct Associate Professor	Ocean circulation and sea ice formation
Terry Wilson, Adjunct Professor	Structural geology and geotectonics

Students

Annette Bolton, PhD candidate	Paleoceanography
Rosie Cody, PhD candidate	Paleoecology and biostratigraphy
Lana Cohen, PhD candidate	Ice core climatology
Alice Doughty, PhD candidate	Glacial modelling
Jeremy Fyke, PhD candidate	Ice/ocean modelling
Rachel Gavey PhD candidate	Marine Geology
Julene Marr, PhD candidate	Marine geochemistry
Molly Patterson, PhD candidate	Sedimentology and paleoclimatology
Joe Prebble, PhD candidate	Palynology
Heather Purdie, PhD candidate	Glaciology and climatology
Rachael Rhodes, PhD candidate	Ice core climatology
Jane Chewings, MSc candidate	Sedimentology
Kylie Christiansen, MSc candidate	Paleoceanography
Nick Cozens, MSc candidate	Petrology
Bella Duncan, MSc candidate	Paleoceanography
Denise Fernandez, MSc candidate	Physical oceanography
Georgia Grant, MSc candidate	Paleoclimatology
Lawrence Kees, MSc candidate	Glaciology and meteorology
Sanne Maas, MSc candidate	Sedimentology and paleoclimatology
Bradley Markle, MSc candidate	Ice core climatology
Karen McKinnon, MSc candidate	Glacial modelling
Rory Mearns, MSc candidate	Palynology
Rebecca O'Donnell, MSc candidate	Glacial modelling
Amy Plant, MSc candidate	Paleoceanography
Matt Ryan, MSc candidate	Quaternary climatology
Stephen Stuart, MSc candidate	Glacial modelling
Evelien van de Ven, MSc candidate	Antarctic crustal evolution
Holly Winton, MSc candidate	Ice core climatology

ARC staff and students eating iceblocks at Scott Base. (L-R): Stephen Mawdesley (GNS Science), Tristan Bennett, Tamsin Falconer, Hedley Berge, Darcy Mandeno, Brad Markle, Nancy Bertler, Heidi Godfrey (Antarctica NZ), Lana Cohen, Jeremy Ridgen, Cliff Atkins (SGEES), Jane Chewings, Brent Alloway (SGEES)

Academics at Victoria University also represent a wide range of interests in the Antarctic region from tourism and law to literature and politics, with significant research in Antarctic biology and the properties of ice. Current University staff outside the ARC with Antarctic interests and expertise are listed below:

Sir Paul Callaghan, Professor of Physics	Properties of sea ice
Margaret Harper, Research Associate in Geology	Freshwater algae
Bill Manhire, Professor of English	Antarctic literature
Mark McGuinness, Associate Professor of Mathematics	Modelling
Joanna Mossop, Senior Lecturer in Law	International law
Ronan O'Toole, Senior Lecturer in Microbiology	Environmental microbiology
Nigel Roberts, Professor of Political Science	Antarctic politics and history
Ken Ryan, Senior Lecturer in Antarctic Biology	Marine algae
Tim Stern, Professor in Geophysics	Solid earth geophysics and Transantarctic Mts
Ross Stevens, Senior Lecturer in Design	Design of remote field camps
Joe Trodahl, Emeritus Professor in Physics	Temperature conduction in ice and rock
Cath Wallace, Senior Lecturer in Business and Public Management	Antarctic environmental issues

Antarctic Climate History from Past Sediments

(ANDRILL Programme and IODP Wilkes Land Margin Project)

The 2010 year was another productive and successful year for the ANDRILL Programme. While ANDRILL is primarily focussed on recovering geological records, much of this year's activity has focussed on writing up results, contextual studies for interpreting the drill core records and site survey work for future drilling. Under the leadership of Dr Richard Levy (GNS Science), the ANDRILL Programme was re-funded for another eight years with a review after three years. ARC receives a subcontract of $500,000 p.a. and is contributing to the analysis of data and publication of results from the existing ANDRILL cores as well as building the case for the planned Coulman High Project scheduled for drilling in 2013-2014. This project will recover physical evidence for the response of the Antarctic ice sheets to high levels of atmospheric CO_2 experienced more than 34 million years ago. A major new component of the programme is an objective led by Andrew Mackintosh aimed at understanding the complex relationship between the East and West Antarctic ice sheets where they meet along the Transantarctic Mountains, thereby enabling new information from drill cores in the Ross Sea to be understood in a more regional context. This work, which involves numerical glacier and ice sheet models validated with field observations, got off to a great start with participation in the combined US-New Zealand field programme in the Central Transantarctic Mountains.

Tim Naish led a small team including Richard, Prof. Gary Wilson (UOtago), and Andy Cole (Antarctica New Zealand), into the Beardmore Glacier to describe fjordal glacial strata exposed on the valley walls at the Cloudmaker and Oliver Bluffs. They experienced superb weather and made detailed descriptions of numerous cycles of glacial advance and retreat. These fossiliferous rocks comprise the infamous Sirius Group and contain fossil beech tree wood, beetles, leaves and mosses representing a time when this region was up to 10°C warmer. The question is when? Tim's team hope to shed some new light on this.

The largest field operation for ANDRILL was site activities carried out at the proposed Coulman High project drill sites. Again this was a collaborative effort between the US and New Zealand, capably led by Dr Frank Rack (ANDRILL Science Management Office) and managed on site by Tamsin Falconer. The aim was to gather a range of environmental data from the ice shelf, water column and seafloor to help in the development of both the operational and scientific plan for the deep drilling. The ANDRILL hot water drill system provided access at three locations through the ice shelf for a comprehensive range of oceanographic measurements conducted jointly by staff from NIWA (Dr Mike Williams and Dr Craig Stuart) and Woods Hole Oceanographic Institution. NIWA also have used this opportunity to deploy a long term mooring at the site which will provide valuable information on sub-ice shelf ocean circulation over the next few years. MSc student Sanne Mass, also supervised by Richard, recovered sediment cores from the sea-floor using the Alfred-Wegener-Institute's gravity corer. Fifteen short sediment cores were collected from beneath the ice shelf and will provide insight into ice shelf dynamics over the past 10,000 years. The final ANDRILL field activity was the "dust devils" led by Cliff Atkins (SGEES) who spent six weeks systematically sampling the sea-ice between the Ferrar and MacKay glaciers in Southern McMurdo Sound. This project aims to quantify the nature and volume of wind-blown dust being contributed to the marine environment. Bio-available Fe in the dust is an important nutrient limiting phytoplankton productivity and the dust is an important component of the ANDRILL sediment cores. MSc student Jane Chewings will work on this project for her thesis.

Richard Levy (GNS Science) and Tim Naish at Oliver Bluffs, Antarctica

Rob McKay participated in an international science team as lead sedimentologist on the Integrated Ocean Drilling Program (IODP) Wilkes Land Margin Expedition in February and March of 2010. The aim of the expedition was to recover geological records of the past dynamics of the East Antarctic Ice Sheet (EAIS) during warmer-than-present climates and their influence on ocean circulation. The Wilkes Land margin is particularly interesting as it lies directly adjacent to one of the potentially most dynamic sectors of the EAIS where the ice sheet is grounded below sea-level. Rob's work is collaborative with Tim and Lionel Carter and is funded by the Royal Society of New Zealand Marsden Fund. Two new students, Molly Patterson and Georgia Grant, will undertake PhD and MSc theses respectively, analysing the cores recovered by the expedition. Rob's team's focus is, understanding the behaviour of the EAIS during a warm Pliocene period, 3 to 5 million years ago – the last time Earth was as warm as it will be in the next 100 years.

Compared to 2009, the publication output has been relatively quiet. However, this has been a frenetic writing year, with a number of manuscripts submitted, in review or in press for 2011. ARC staff are leading or co-authoring eight papers in press for a special issue of *Global and Planetary Change* on the ANDRILL McMurdo Ice Shelf (MIS) Project. Rob leads a multi-author paper submitted to *Nature* presenting new knowledge from the ANDRILL MIS core on the role of Antarctica in global cooling that lead to Northern Hemisphere glaciations. Tim is a co-author on a paper in review in *Science* that reconciles global sea-level and ice volume during the warm Pliocene. PhD student Rosie Cody has submitted a multi-authored manuscript to *Science* that shows affect of climate change on the evolution of phytoplankton in the Southern Ocean. Gavin Dunbar has new temperature data from Ross Sea sediment cores for a "super-interglacial" warm period around 1 million years ago that he is working on with US climate and ice sheet modellers. Richard and Nick Golledge have a paper in review in the *Journal of Geophysical Research* that models the Ferrar Glacier under warmer climate conditions – a first step in our goal of reconciling the contrasting glacial histories of the West and East Antarctic ice sheets.

Gary Wilson (UOtago) and Tim Naish scaling the slopes of the Cloudmaker, Antarctica

Southwest Pacific and Southern Ocean Paleoceanography

(including ANZICE Programme)

The paleoceanographic research group includes the ANZICE (Antarctica-New Zealand Interglacial Climate Extremes) Programme. Two objectives within ANZICE include research in ice core climatology and glaciology and glacial modelling both reported in more depth in the following two separate sections. The ANZICE programme contributed to the SCAR-commissioned report "*Antarctic Climate Change and the Environment*". This report is the first comprehensive overview of changes in the Antarctic and provides over 30 recommendations for future scientific and policy initiatives. It is the most up-to-date and comprehensive analysis on the state of the Antarctic continent and surrounding Southern Ocean. The success of the ANZICE Programme was also an important factor in leveraging funds for an ice core drill to obtain cores to 1,000 m below the surface. Further updates on the development and testing of the drill can be found within the Ice Core Drilling and Science Drilling Office activity sections.

While it is obvious to a Wellingtonian in a "southerly" that there are close links with Antarctica, modern climate science has only recently discovered that a climate signal termed the Antarctic Southern Annular Mode (SAM) is a major influence on New Zealand along with the much better known El Nino-La Nina (ENSO) cycles from the tropical Pacific. New research by Lionel Carter from Lake Tutira, just north of Napier, has identified the effects of these two major climate drivers for a record extending back 7000 years that includes times of increased warmth. A detailed record of past storms, preserved in lake deposits, shows periods of strong and weak storm activity that relate to times when SAM and ENSO reinforce one another (strong activity) and work against one another (weak activity).

The general knowledge and insights gained from ANZICE are also guiding applied research by Lionel Carter into submarine telecommunications. Because the global network of submarine fibre-optic cables underpins the Internet and 97% of international communications and data traffic, cable owners/operators wish to be informed of potential natural hazards including those relating to climate change (increased storminess and floods, rising sea level, changes in human activities) in order to protect this critical infrastructure. Some of this research was published in a report prepared jointly with the United Nations Environmental Programme.

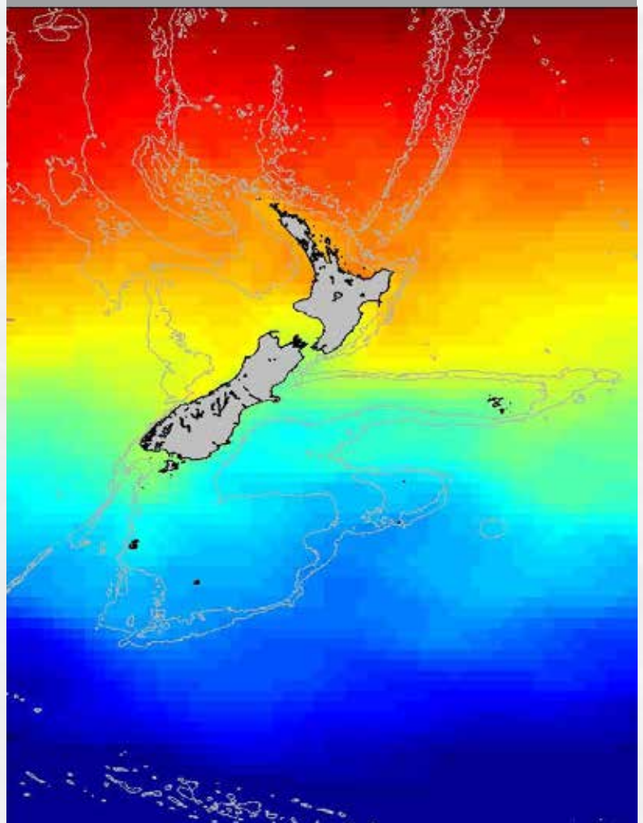
The ratio of magnesium to calcium within the shells of minute marine plankton is an indicator of ocean temperature – a key factor when evaluating past change. Students Annette Bolton and Julene Marr, with supervision from Lionel, Gavin Dunbar, and Joel Baker (SGEES), have completed calibrations for the magnesium/calcium technique for three modern plankton species. The students are now turning these data to fossil plankton preserved in sediment cores to provide, for example, realistic temperatures of the upper ocean during the last major global warm period, 127,000 years ago. Because the three plankton species live at different levels in the upper ocean, the temperature data will provide an insight into the thermal structure of the marine "plankton factory", how that has changed with time and the repercussions of those changes.

The development of a computer-based model by PhD student Jeremy Fyke, supervised by Lionel, Andrew Mackintosh and Dr Andrew Weaver (University of Victoria, Canada), the captures the effects of atmospheric warming on Earth's ice-atmosphere-ocean system, is a major undertaking. Nevertheless a major break-though has been achieved by integrating two state-of-the-art models. The new combined model has been tested against well described warm periods that include the post-industrial revolution, the warming that followed the last ice age, and the last major global warming to see if the model reproduced changes identified by other means techniques. Not only did the model successfully simulate known past changes, but importantly provided insights into future changes and environmental responses that were either unknown or uncertain.

A series of public information and policy papers have been prepared by Dr Sean Weaver and the ANZICE group for inclusion on the ANZICE webpage [http://www.victoria.ac.nz/antarctic/research/anzice.aspx]. The papers are plain language reviews of the ANZICE research, what it plans to achieve, and the policy implications of the research. These papers are accompanied by podcasts of various ANZICE scientists talking about their work.

ANZICE was also fortunate to co-host (with Dr Sean Weaver) Khandu Patel, a recipient of a New Zealand Science, Mathematics & Technology Fellowship for the period 2 February 2010 – 2 July 2010. During that time Khandu interacted with staff in the ARC and SGEES with the focus on the science of past climate change as well as general aspects of earth sciences that included attendance at lectures, visiting laboratory facilities and involvement in field trips. His fellowship was a great success with Khandu and ANZICE gaining valuable insights into science education from primary school to university.

Sea surface temperatures around New Zealand



The ocean plays a prominent role in the climate system, yet many aspects of how it operates are poorly understood. Recent studies show the role of the wind in driving the ocean's circulation has been underestimated. During 2010 research by Melissa Bowen and MSc student, Denise Fernandez, with funding from the Morgan Family Charitable Foundation, has found that South Pacific winds may determine how much Antarctic Circumpolar Current water flows into the New Zealand region along the Campbell Plateau. The results were based on observations from satellites collected over the past two decades and extended to describe the glacial and interglacial variations of the sub-polar inflow to the New Zealand region. The results have implications for the flow of the Antarctic Circumpolar Current in other ocean basins and have been presented at several conferences.

Ice Core Climatology

(also an ANZICE objective)

Ice core research in 2010 focussed on the Roosevelt Island Climate Evolution (RICE) project. The aim of this international New Zealand-led project is to recover a high resolution record to improve our understanding of the stability of the Ross Ice Shelf and West Antarctic Ice Sheet (WAIS) in a warming world. The RICE ice core is expected to provide an annually resolved record for the past 30,000 years, a time period when Antarctica experienced significant warming that ended the last ice age. This extremely high resolution record will allow the team to establish how quickly the Ross Ice Shelf retreated as temperature and greenhouse gas concentration increased. Previous research by the New Zealand-led ANDRILL Programme has found that when the Ross Ice Shelf disappeared in the past, the WAIS became unstable and disintegrated. The stability of the WAIS is highlighted as a major concern and uncertainty in the latest report of the Intergovernmental Panel on Climate Change (IPCC), the UN authority for assessment and advice on climate change and its potential consequences to society. Nancy Bertler is the principal investigator of the project and will lead the field seasons together with collaborators from the United States, Denmark, Germany, Great Britain, Australia, and Italy. The recovered 750 m deep ice core will be jointly processed with all collaborators in the New Zealand Ice Core Research Facility at GNS Science in Lower Hutt. In preparation for the drilling at Roosevelt Island, Alex Pyne and Darcy Mandeno tested the new New Zealand intermediate depth ice core drill in Greenland in July as part of the NEEM project. During the 2010/11 Antarctic field season, the RICE team, including two ARC graduate students, Lana Cohen and Bradley Markle successfully completed all site survey work with colleagues from the USA and Great Britain. This included the deployment of an automatic weather station, installation and survey of a 200 km array of mass balance devices, and many kilometres of high resolution ground penetrating radar measurements. Furthermore, the group recovered a number of 10 m deep firn cores, collected over 1,000 snow samples from snow pits and from snow fall during storm precipitation, and winterised over 50,000 lbs of equipment on Roosevelt Island in preparation for the commencement of the drilling during the 2011/12 field season.

Darcy Mandeno and Lana Cohen looking at the seasonal stratigraphy in a snow pit, Roosevelt Island

RICE team at Roosevelt Island during 2010/2011 field season

The Ice Core Climatology group is jointly staffed between the ARC and GNS Science. During 2010, PhD students, Rachael Rhodes and Lana Cohen, and MSc students, Holly Winton and Bradley Markle, conducted their research within the ice core programme. Bradley joined the team during 2010 on a Fulbright Scholarship. His thesis focuses on distinguishing between East and West Antarctic climate signals in the Ross Sea Region by interpreting the Gawn Ice Piedmont ice core using stable isotope and geochemical analysis combined with air mass trajectory modelling. Bradley is supervised by Nancy Bertler, Joel Baker (SGEES), and Kate Sinclair (GNS Science). Furthermore, a government subsidised scholarship for undergraduate student, Rebecca Pyne, enabled her to work in the ice core facility to gain work experience in scientific analysis. Rebecca helped with the processing and analysis of the Whitehall Glacier ice core record under the supervision of Kate and Nancy. Holly Winton received a scholarship to visit Prof. Barbara Delmonte at the University of Milan for four weeks to analyse the grain size of dust particles extracted from snow samples from McMurdo Sound. Holly, supervised by Nancy, Joel and Gavin Dunbar, aims to quantify the iron flux into the Ross Sea, a region of Antarctic Bottom Water formation and hence carbon sequestration.

During 2010 we contributed or led a number of publications. In particular, Nancy and Peter Barrett contributed the chapter, "*Vanishing Ice Sheets*" in the UN commissioned publication, *Changing Climates, Earth Systems, and Society*. A number of distinguished scientists, ambassadors, and policy makers also visited the ice core research group and facilities in 2010. We were particularly pleased to welcome Prof. Kendrick Taylor Research Professor with the Division of Hydrologic Sciences at the Desert Research Institute and Chief Scientist of the WAIS Programme.

Glaciers and Climate Change in New Zealand and East Antarctica

(also an ANZICE objective)

The glaciology group expanded in 2010, and numbered six staff; Andrew Mackintosh, Brian Anderson, Nick Golledge, Dan Zwartz, Huw Horgan, and visiting Research Fellow Ruzica Dadic, and seven students; Alice Doughty (PhD), Jeremy Fyke (PhD), Heather Purdie (PhD), Lawrence Kees (MSc), Karen McKinnon (MSc), Rebecca O'Donnell (MSc) and Stephen Stuart (MSc). The group is working on interwoven projects in the Southern Alps and Antarctica, developing models but also collecting glaciological and geological data to constrain them.

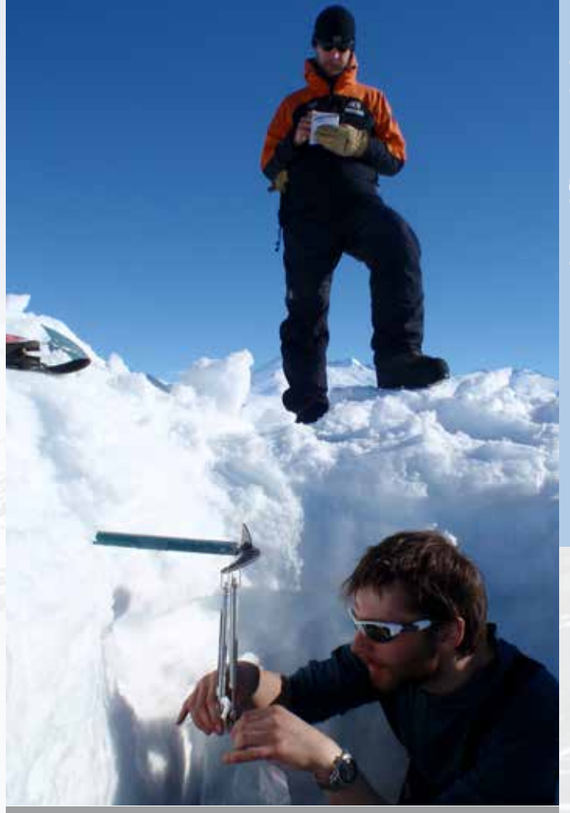
Two students submitted their theses in 2010, Heather and Rebecca. Heather's thesis *"Controls on spatial and temporal variation in snow accumulation on glaciers in the Southern Alps, New Zealand*" aimed to better understand how snow accumulation varies on mid-latitude maritime glaciers, and centered on the Tasman and Franz Josef glaciers. Heather has published several papers about snow accumulation processes in the Southern Alps as part of this research. The research included collaboration with Nancy Bertler, Joel Baker (SGEES), and Wendy Lawson (UCanterbury). Rebecca's MSc thesis "*Modelling Quaternary glacier extent and climate in Tasmania, Australia*" has been simulating the ice cap that developed in Tasmania at the Last Glacial Maximum to improve the understanding of Quaternary glaciations in Tasmania and in particular, why Southern Hemisphere 'Ice Ages' occur. Her work was supervised by Andrew, Nick and Dr Alun Hubbard (University of Wales, Aberystwyth).

Lawrence and Brian have been measuring snow accumulation and seasonal precipitation rates in high altitude, trans-alpine areas using Ground Penetrating Radar (GPR). The study areas were based in the Ka roimata o hine hukatere/Waiho and Pukaki (Davis Snowfield, Annette Plateau and Jollie River valley) catchments. This work has been in collaboration with the GNS Science Ice Core Project led by Dr Uwe Morgenstern. Stephen Stuart has also been improving our understanding of precipitation patterns using data from weather stations, with the support of Dr Sam Dean (NIWA), and this data is now being used in our glacial modelling exercises.

On the modelling front, Brian, Andrew and several others published an energy balance modelling study of the Brewster Glacier (*Journal of Glaciology*), which revealed how sensitive New Zealand glaciers and meltwater runoff are to increasing temperature. Andrew, Nick Golledge and US/Australian collaborators also had a paper accepted in *Nature Geoscience*, where they attempted to understand the processes that caused the retreat of the East Antarctic Ice Sheet from the Last Glacial Maximum. This paper will appear in the March 2011 edition.

Nick has applied the Parallel Ice Sheet Model from the University of Alaska, Fairbanks to both New Zealand glaciers and the Antarctic Ice Sheet, and this work will be published over the next 12 months. Nick visited Fairbanks in October, as the recipient of the S.T. Lee Young Researcher Award, to work with Prof. Ed Bueler and others on the model. In December, Nick also lead a glaciology team comprising Dr Wolfgang Rack and Oliver Marsh (UCanterbury), and mountaineer, Dean Arthur, to Beardmore Glacier, Transantarctic Mountains. They aims were investigated the junction between the grounded glacier ice and the (floating) Ross Ice Shelf using ice penetrating radar, GPS surveying and time-lapse photogrammetry. Once processed, all of these data will be combined and used to constrain a numerical model of the glacier, giving a better understanding of how these important glaciers behave both now and during periods of environmental change.

New MSc student, Karen McKinnon is using a glacier model to study the response of the Tasman Glacier to climate forcing, and is currently investigating the role of changing bed topography on glacier behaviour.



Oliver Marsh (front) and Nick Golledge conducting density measurements at Beardmore Glacier, Transantarctic Mountains (Photo: Oliver Marsh)

Brian Anderson and Lawrence Kees in a snow pit during site survey work, Annette Plateau, Mt Cook

Jeremy was nearing the completion of his PhD study involving simulating the response of Greenland and Antarctic ice sheets to future climate change, by coupling Dr David Pollard's (Pennsylvania State University) ice sheet model to the University of Victoria's (Canada), Earth Systems model, with the support of Prof. Andrew Weaver (UVic, Canada).

Alice's research focusses on understanding the fundamental climate dynamics in New Zealand during the Late Glacial and Holocene. As part of this research she attended the European Glaciology Modelling Summer School in Karthaus, Italy (run by Prof. Hans Oerlemans). Alice has also recently co-authored papers in *Nature* and *Nature Geoscience* on New Zealand moraine chronologies, in association with the Columbia University/Lamont and University of Maine groups.

Finally, Dan is using his own geological data and geophysical modelling to learn about changes in Antarctic Ice Sheets since the LGM. He assisted Andrew in his *Nature Geoscience* study, helped Peter Barrett with his IODP work, and contributed to an information document on sea level change from the Royal Society.

Science Drilling Office

The members of the Science Drilling Office (SDO) are Alex Pyne, Tamsin Falconer and Darcy Mandeno. They have had a busy and successful year in 2010 with a focus on two major projects; ANDRILL and the development of an ice core drill.

ANDRILL has begun planning and preliminary work for a new round of drilling at Coulman High, a site at the edge of the Ross Ice Shelf approximately 50 km east of Ross Island (Cape Crozier) which has been characterised by ship board seismic. This site promises to be a significant new challenge, with the ice shelf moving about two metres per day, and the site requiring an over ice traverse route of 150 km from McMurdo Station and Scott Base.

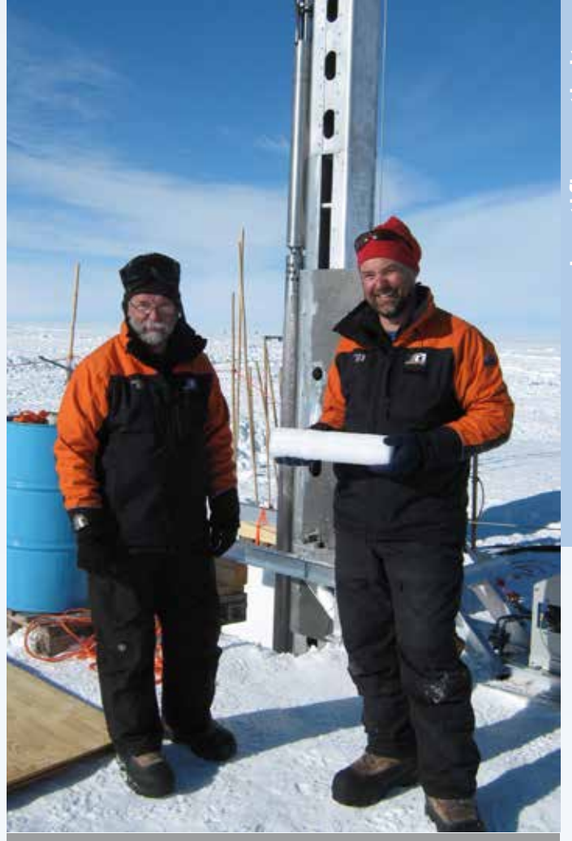
In August, Tamsin presented a Project Plan and Budget for drilling two sites at Coulman High to interested scientists and prospective Programme Operators (including the previous ANDRILL Operations Management Group) at SCAR Buenos Aires. The development of the Project Plan and Budget and Tamsin's travel to Buenos Aires was funded by Antarctica New Zealand and the Alfred Wegener Institute.

Over the 2010/11 summer season, Tamsin acted as field coordinator for the first part of the ANDRILL Coulman High Site Survey. Activities on site were focussed on testing and developing procedures for equipment, and gathering data required for future drilling operations. Tamsin worked on the site survey planning with ANDRILL Science Management Office and Raytheon staff during the year, and also worked with people from NIWA, GNS Science, University of Nebraska, Moss Landing Marine Labs, University of California, University of Otago, University of Kansas and Woods Hole Oceanographic Institution. The field season was highly successful.

Darcy and Alex worked on the development of an electro mechanical intermediate depth ice core drill based on the Danish Hans Tausen design which was the prototype for the longer EPICA drills. The drill will be used to support the New Zealand ITASE programme in Antarctica led by Nancy Bertler which is a collaborative programme between VUW/ARC, GNS Science and Antarctica New Zealand.

The drill was tested at the NEEM site in Greenland by Darcy and Alex. The testing programme was successful and most parts of the drill performed satisfactorily; but some parts required modifications to improve the overall performance of the drill. The SDO were very grateful

Tamsin Falconer "winch watching", Coulmin High, Antarctica



Alex Pyne and Darcy Mandeno with the first ice core from the new ice core drill, NEEM Greenland

Richard Levy (GNS Science), Jeremy Ridgen and Sanne Maas recovering the gravity corer, Coulmin High, Antarctica

to Prof. Dorthe Dahl-Jensen and the NEEM steering committee who hosted the testing at NEEM and also Prof. Charlie Bentley (IDDO), Dr Simon Stephenson (NSF OPP) and Robin Abbot (Polar Field Services) who enabled our 1500 kg drill to be transported to and from Greenland by the USAF 109th Air National Guard.

Regrettably the return of the drill to New Zealand from New York by commercial air freight was significantly delayed which compromised our ability to make the modifications in time for the beginning of the Antarctic season in early October. A difficult decision was made in not attempting to drill this season at Roosevelt Island. In retrospect this was the right decision, especially since the early season weather at Scott Base and Roosevelt Island meant significant delays to flying personnel and equipment into the field. We had a successful preparation season and put us in a better position for an earlier start to drilling next season.

Significant Events

Research Vessels Visit Wellington

The IODP Drill ship, the *JOIDES Resolution*, visited Wellington in January after a successful drilling expedition in offshore Canterbury, and prior to its departure on the Wilkes Land cruise (offshore Antarctica). ARC researcher Rob McKay was one of the scientists on board for the Wilkes Land leg. Rob's participation is the focus of his Foundation for Research Science & Technology Post-Doctoral Fellowship, which supports his research for three years.

While the *JOIDES Resolution* was moored in Wellington in early January, GNS Science and ARC hosted a series of events, including ship tours for invited guests, a media briefing on board, public lectures and a seven-day holiday programme run by geologists from GNS Science with the help of staff and students from Victoria University. Students and invited guests got to view the state-of-the-art laboratories and the drilling and core storage facilities on board.

ARC staff were also fortunate to go on board both the German Research Vessel *Polarstern* and the Korean Icebreaker *Aaron* when they visited Wellington during 2010.

Joides Resolution docked in Wellington Harbour

NZ Antarctic Medal recipients (L-R): Alex Pyne, Peter Barrett and Tim Naish

New Zealand Antarctic Medals

Peter Barrett, Tim Naish and Alex Pyne were honoured in April 2010 at three different investiture ceremonies at Premier House with the award of the New Zealand Antarctic Medal. Peter received the medal for services to Antarctic science, Tim for services to Antarctic climate science and Alex for services to Antarctic engineering. The New Zealand Antarctic Medal was formally instituted in 2006 as a replacement to the (British) Polar Medal and given to a team or individuals who have made an outstanding contribution to exploration, scientific research, conservation, environmental protection, or knowledge of the Antarctic region. It is the first time the medal has been awarded to more than one person from the same institution, and also to previous recipients of the Polar Medal, such as Peter and Alex.

NZ Antarctic Medal (back)

New Zealand-USA Joint Commission Meeting

In January, the ARC hosted a workshop which brought together Antarctic researchers from around New Zealand with funders and stakeholders and their American counterparts. The one-day workshop fed into a larger Joint Commission Meeting held the following day. The meeting was organised by the Ministry of Research Science and Technology (MoRST) and US Department of State to promote closer collaboration between US and New Zealand research organisations. The Antarctic workshop was chaired by Tim Naish and Dr Ed Butler (Antarctica New Zealand). US visitors included Dr Frank Rack (ANDRILL Science Management Office), and Dr Jerry Mullen (United States Geological Suvey). US Ambassador, David Huebner joined part of the session. Workshop participants advocated continuing to build existing collaborations (such as ANDRILL and ITASE) and working towards a collaborative marine ecosystems project using the highly successful approach of the Long-Term Ecological Response Programme. At the formal Joint Commission Meeting, Antarctic research collaborations were held up by Dr Helen Anderson (CEO of MoRST), as a model that other research areas could follow for future US-New Zealand collaborative projects.

Annual S.T. Lee Lecture in Antarctic Studies

Distinguished NASA scientist, Dr Robert Bindschadler presented the 2010 S.T. Lee Lecture in Antarctic Studies at Victoria University on 19 May. Dr Bindschadler's lecture, *"Waking Giants: Ice Sheets in a Warming World"*, drew on his extensive research, in particular, numerous unique applications of remote sensing data for glaciological research including measuring ice velocity and elevation using both visible and radar imagery, monitoring melt of the ice sheet by microwave emissions, and detecting changes in icesheet volume by repeat space-borne radar altimetry. In his lecture, Dr Bindschadler noted that the great ice sheets of Greenland and Antarctica are shrinking faster and faster, increasing the rate of sea level rise and that observations of this accelerating ice loss have surprised the experts and confounded the predictive models that policy makers might rely on to take action. He described the direct field studies and how they have identified a number of causes for the sudden awakening of the ice sheets and suggested that the analogue of tidewater glacier retreat casts a disheartening picture that continued ice sheet mass loss may well be irreversible.

The S.T. Lee Lecture series is supported by an endowment to the Victoria University Foundation from Lee Seng Tee. Additional support for the 2010 lecture was provided by the New Zealand American Association.

Dr Robert Bindschadler presenting the S.T. Lee Lecture, Rutherford House, Wellington

Oslo International Polar Year Conference

Tim Naish and Nancy Bertler attended the International Polar Year (IPY) meeting in Oslo, Norway in June, where more than 2000 polar researchers came together to present the key new results from the intense research activities carried out in the polar regions during the IPY period. They co-convened a theme on *Climate and Paleoclimate Processes and Dynamics*, in which new results from ANDRILL Progam, Integrated Ocean Drilling Program, Inter-Continental Drilling Programme, ice coring programmes and a range of initiatives in the Arctic were presented. An important emphasis was the inter-connectedness of the polar regions and their influence on global climate. Tim was involved as a mentor participating on panels for the Association of Polar Early Career Researchers, and he participated in a live BBC media interview in the Plenary Hall on climate change issues and IPCC.

Scientific Committee on Antarctic Research Open Science Conference

Several ARC staff attended the Scientific Committee on Antarctic Research (SCAR) Open Science Conference in Buenos Aires in August. Tim Naish and Andrew Mackintosh chaired a stimulating science session on *Antarctic Deglaciations: Mechanisms, Timing and Character*, at which both Tim, Andrew and Lionel Carter all gave oral presentations. Peter Barrett was involved with meetings and presentations as part of the ANTscape group, a group working on paleotopographic reconstructions for the Antarctic continent for use in past climate reconstructions and modelling.

Tamsin Falconer, together with Dr Richard Levy (GNS Science) and Dr Frank Rack (ANDRILL Science Management Office) presented an update on Coulman High to interested scientists, and to the ANDRILL Operations Management Group (AOMG). Tamsin's presentation gave an overview of a draft project plan and budget for Coulman High, which she and Alex Pyne had developed. Tim was also involved in presenting the latest information on the scientific objectives and planning for Coulman High. Both science and operational information was well received, with new countries such as South Korea expressing strong desire to join in ANDRILL for Coulman High.

(L-R): Prof. David Bibby, Pro Vice-Chancellor & Dean of Science; Prof. Lionel Carter; and Prof. Neil Quigley, Deputy Vice-Chancellor -Research, at Lionel's inaugural lecture

Inaugural Professorial Lecture

Lionel Carter delivered his inaugural professorial lecture on 14 September, 2010. Titled "*Between Pole and Equator: the New Zealand ocean in a changing world*", the lecture explored the effects of Antarctic and tropical climate drivers on the New Zealand ocean, both now and in the past, and their interaction with major plate boundary processes such as earthquakes and volcanic eruptions which result from New Zealand's plate boundary setting. In the lecture, Lionel explained how studies can help identify and resolve environmental problems associated with the present phase of climate change. In the second part of the lecture, he looked at problems associated with potential catastrophic ice loss from Antarctica and disruption of the submarine telecommunications network that underpins international data transfer and communications as well as the internet.

Colin Bull (1928-2010)

In September, the ARC held a brief seminar to commemorate the life and contributions of Colin Bull, remembered in Antarctica by the prominent landmark of Bull Pass. Colin was Senior Lecturer in Physics at Victoria University from 1956-61 and leader of the second VUW Antarctic Expedition in 1958-59. By dint of personality, vision and administrative style he had a lasting influence on Antarctic research at Victoria University, and glaciology world-wide, through his role as Professor and later Dean at The Ohio State University.

Colin acquired several degrees from Birmingham University (1945-51), following which as a Cambridge Post-Doctoral Fellow he led several expeditions to the Arctic. He then married Gillian and came to VUW. In 1961 he, Gillian and family left VUW for The Ohio State University (OSU) in Columbus, where he became Assistant then Associate then Professor of Geology, Director of the Institute of Polar Studies (1965-69), chairman of Geology (1970-76) and Dean of the Faculty of Mathematics and Engineering (1976-86). He retired with Gillian to become an Emeritus Professor and Polar Bibliophile on Bainbridge Island, near Seattle. In his career he attracted and inspired a number of staff and graduate students, including pioneering glacial geologist John Mercer, glaciologists Ian Whillans and Lonnie Thompson, and VUW's Peter Barrett. He also attracted VUW's first Antarctic student (with Barrie McKelvey) and geologist Peter Webb to become Chairman of Geology at OSU for many years. This added significantly to the OSU-VUW connection, as Peter also led the US component of a partnership with VUW in Antarctic offshore scientific drilling in the period 1970-2001. Colin passed away on 7 September 2010 on the first night of a cruise to coastal Alaska to take Gillian to past research areas. As Peter Webb noted "Colin would be pleased to reflect on the fact that both he and Shackleton checked out while on a ship headed into the high latitudes."

Colin Bull sitting in his study at home (Photo: Peter Barrett)

S.T. Lee Young Researcher

From 4-12 October, ARC researcher Nick Golledge travelled to the International Arctic Research Center (IARC), University of Alaska-Fairbanks (UAF) as the recipient of the 2010 S.T. Lee Young Researcher Award. The highlights of this collaboration are outlined below.

Ice-sheet modelling at the ARC has traditionally employed one-dimensional ('flowline') models, which have the advantage of being relatively simple to formulate and which are quick to run. However, in order to understand wider spatial patterns of ice sheet behaviour, a three-dimensional model is essential. Since March 2009, attempts have been underway at VUW to simulate Last Glacial Maximum (LGM) ice sheets on both New Zealand and Antarctic domains with 3D models. In order to do this successfully at high spatial resolution, and in order to fully capture the physical processes governing ice sheet behaviour, a sophisticated ice sheet model is necessary. Yet few such models are able to make use of parallel processing capabilities, and consequently are considerably restricted in their application to high-resolution studies. The '*Parallel Ice Sheet Model*' (PISM), developed by Dr Ed Bueler and colleagues at University of Alaska-Fairbanks, is an exception, and combines both great sophistication (in terms of model physics) with parallel computation.

Initial contact was made with Dr. Bueler in August 2009, and with the assistance of his group at the UAF, as well as VUW staff in the Engineering and Computer Sciences department, ARC staff have now compiled numerous version of the model code (both stable and developmental releases) on a range of computers (laptop, desktop, 8-core server, 32-core cluster, 4096-core BlueGene supercomputer). The complexities involved in both the computational practicalities as well as modelling methodology meant that initially,

Nick Golledge, S.T. Lee Young Researcher

developmental progress outweighed scientific advances. The opportunity to spend time at UAF therefore allowed the possibility for consolidating much of the developmental work and making greater steps towards the scientific goals. The timing of the visit (October 2010) also overlapped with a two-day PISM workshop and the annual Northwest Glaciologist's Meeting.

VUW's success in winning the top prize in the University of Canterbury 'Grand Challenge' competition means that we now have dedicated access to their entire supercomputer facility for three weeks continuous runtime, enabling us to carry out experiments that will attempt to simulate glacier fluctuations of the recent geological past, as well looking forward through the next century.

Endowed development recepient Meghana Rajanahally

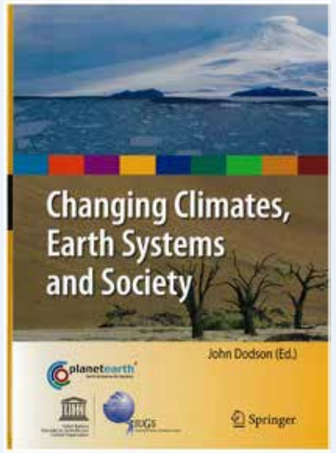
Endowed Development Fund

The Victoria University Foundation holds approximately $450,000 in the ARC Endowed Development Fund. This substantial fund enables us to give grants to students for conference travel, workshops or other extensions to their research. This year's recipients included Rachael Rhodes, Holly Winton and Matt Ryan from the ARC, Julene Marr from SGEES, as well as Rebecca Cowie, Eileen Koh, and Meghana Rajanahally from the School of Biological Sciences. The funding helped cover costs of attendance at a symposium on Sea Ice in the Physical & Biogeochemical System in Tromso, the International Polar Year (IPY) Conference in Oslo, the American Geophysical Union Conference in San Francisco and time to write up papers from MSc research.

Funding Success

- $133K for staffing of the ANDRILL Coulman High field season from Antarctica New Zealand;
- $100K for equipment required for the ANDRILL Coulman High field season, from the ANDRILL Science Management Office;
- $50K for the development of a Project Plan and Budget for ANDRILL Coulman High, from Antarctica New Zealand;
- $50K to pay a contribution to the NZ IODP membership fee, from funds held by the Deputy Vice Chancellor – Research;
- $45K to support post-production of the Climate Change film, from funds held by the Deputy Vice Chancellor – Research;
- $20K from the University Research Fund to Gavin Dunbar for research into Foraminifera;
- $10K from LINZ for support of the Cape Roberts Tide Gauge
- $3K from NIWA for research into Glass Eel Migration patterns, to Melissa Bowen;
- 1 million hours computing time on the BlueFern Supercomputer for Nick Golledge to run models of past glacial conditions;
- Support for conference and workshop travel from: Ministry for the Environment for Andrew Mackintosh and Tim Naish, from NIWA for Tim Naish, from the US National Academies (USA) for Tim Naish, from IODP for Peter Barrett, and from SCAR for Rob McKay.

Book Release



The United Nations Educational, Scientific and Cultural Organisation (UNESCO) and the International Union of Geological Sciences (IUGS) jointly initiated the International Year of Planet Earth (IYPE), which grew into a triennium from 2007-2009. The purpose of IYPE is to raise public and political awareness of earth sciences potential to improve people's quality of life and to protect the environment. The publication on "*Changing Climates, Earth Systems and Society*" is an important achievement of the substantial public outreach effort of the IYPE programme. Peter Barrett and Nancy Bertler were invited to contribute a chapter on "*Vanishing Polar Ice Sheets*". The chapter contrasts historical changes in Antarctica and Greenland through major climate transitions over the past 50 million years with current observations, including accelerating loss of ice from polar ice sheets, increasing sea-level, collapsing ice shelves, warming and acidification of the ocean, and changing ocean currents and atmospheric circulation. Based on their review of the past climate history and the worrisome changes during modern times, Peter and Nancy close the chapter with an appeal to the reader, that choices made now, will affect the global system for millennia to come.

Awards & Appointments

Peter Barrett, **Tim Naish** and **Alex Pyne** were honoured with the New Zealand Antarctic Medal in the 2010 New Years Honours List.

Tim Naish appointed Lead Author, Intergovernmental Panel on Climate Change (IPCC) AR5, Working Group 1.

Andrew Mackintosh was appointed to the editorial board of Geology (2010-2012).

Tim Naish appointed to US National Academy of Sciences, National Research Council Committee to review US scientific ocean drilling programs and make recommendations on a future US$1B science plan to National Science Foundation.

Peter Barrett appointed to the Science Writing Committee of the new science plan for future scientific ocean drilling.

Ruzica Dadic was granted a 2-year Swiss Post-Doctoral Fellowship to work at the ARC.

Alice Doughty was successful in gaining a place at the Karthaus glaciology summer school in northern Italy.

Nick Golledge awarded the BlueFern High Performance Computing University of Canterbury Grand Challenge.

Molly Patterson was awarded a VUW PhD scholarship.

Holly Winton awarded the Antarctica New Zealand New Zealand Post Scholarship (MSc).

Bradley Markle recipient of a Fulbright Scholarship (MSc).

Teaching Programme

The Antarctic Research Centre supports a significant proportion of the research being carried out in the paleoclimatology research theme in SGEES. There is also close interaction between ARC staff and projects with other research programmes in geophysics, geology, physical geography, and the environmental studies programme. The teaching programme also includes supervision of graduate students at MSc and PhD levels.

Staff of the ARC contributed to teaching in SGEES in the following courses in 2010:

ESCI 111	Earth Systems & Global Change: An Introduction to Earth Sciences
ESCI 112	Fundamentals of Geology
ESCI 132	Antarctica: Unfreezing the Continent
ESCI 201	Climate Change and NZ's Future
ESCI 204	Petrology and Microscopy
GEOG 220	Hydrology and Climate
ESCI 241	Introductory Field Geology
ESCI 301	Global Change: Earth Processes and History
GEOG 323	Advanced Physical Environmental Processes
ESCI 403	Stratigraphy and Palaeontology
ESCI 404	Special Topics
ESCI 412	Quaternary Geology
PHYG 414	Climate Change: Lessons from the Past
PHYG 416	Special Topic B
ESCI 440	Directed Individual Study
PHYG 580	Research Preparation

ARC staff are particularly involved in ESCI 132 as it relates to Antarctica specifically and are the course co-ordinators for ESCI 201 and ESCI 301. The following outlines in more detail these three courses:

ESCI 132 - Antarctica: Unfreezing the Continent

Although primarily an introduction to the natural history of the Antarctic continent many other diverse topics are covered including:

- History of exploration of the continent;
- Antarctica's role as a recorder of past climate change;
- Its importance in any future change in climate;
- The geological history of Antarctica and the development of the ice sheets;
- The history of life on the continent;
- The human experience in Antarctica.

ESCI 201 - Climate Change and NZ's Future

Victoria University's involvement with research in climate history provides the background to this course. The course covers climate change from a variety of perspectives including:

- The causes and effects of climate change;
- Human-caused vs natural climate variability;
- Greenhouse gases and the role of fossil fuels;
- Climate scenarios for the future and their implications;
- Matauranga Maori ideas and its relevance;
- How government policy is responding to climate change;
- The Kyoto protocol and its implications for New Zealand.

ESCI 301 - Global Change: Earth Processes and History

This course aims to better understand and interpret evidence from the geological record of environmental change and how this knowledge can be used to help predict future variability through observational and numerical models. The main topics are:

- The dynamics and effects of polar and mountain ice systems;
- The processes controlling the modern ocean;
- Proxies of past environmental change in the world's oceans;
- Cenozoic evolution and variability of global climate and oceans.

The following six ARC students completed their theses in 2010:

Heather Purdie awarded a PhD in Physical Geography for her thesis *"Controls on spatial and temporal variation in snow accumulation on glaciers in the Southern Alps, New Zealand*". Supervised by Andrew Mackintosh, Brian Anderson and Assoc. Prof. Wendy Lawson (UCanterbury).

Rory Mearns completed his MSc thesis "*Marine palynomorphs from the Plio- Pleistocene interval of the AND-1B Drill-Core McMurdo Sound, Antarctica*". Supervised by Mike Hannah (SGEES) and Tim Naish.

Rebecca O'Donnell awarded an MSc in Physical Geography with First Class Honours for her thesis "*Modelling Quaternary glacier extent and climate in Tasmania, Australia*". Supervised by Andrew Mackintosh, Nick Golledge and Dr Alun Hubbard (UWales, Aberystwyth).

Matt Ryan completed his MSc thesis "*A palynological record of the vegetation and climate of Westland since 210 ka*". He was supervised by Gavin Dunbar and Michael Hannah (SGEES).

Matt Stevens completed his MSc thesis "*Miocene and Pliocene silicic Coromandel Volcanic Zone tephras from ODP Site 1124-C: Petrogenetic applications and temporal evolution*". Supervised by Lionel Carter and Joel Baker (SGEES).

Evelien van de Ven completed her MSc thesis "*Sedimentology and zircon geochronology of the CIROS-1 drill core, Ross Sea, Antarctica*". Supervised by Tim Naish and Joel Baker (SGEES).

ESCI 201 students presenting their climate change posters

Collaborations

Joint Antarctic Research Institute (JARI)

JARI is an unincorporated joint venture between Universities and Crown Research Institutes to develop common interests and objectives in relation to scientific research in Antarctica and Antarctica's relationship to New Zealand in the fields of climate change, glaciology, geology, geophysics, and oceanography. JARI's approach is to foster a culture of openness, information-sharing, cooperation and to promote a positive influence on New Zealand's investment in Antarctic research, including developing linkages between students, research institutes, commercial enterprises and key stakeholders with interests and expertise in the Antarctic. The University of Otago have now joined JARI, with Professors Gary Wilson and Keith Hunter joining the Board. Current board members are Alex Malahoff (Chair, GNS Science), Ian Graham (GNS Science), David Bibby (VUW), Mike Hannah (VUW), Rob Murdoch (NIWA), David Wratt (NIWA), Gary Wilson (UOtago), Keith Hunter (UOtago). Progress is being made towards the University of Canterbury joining the JARI which is likely to be formalised in early 2011. The JARI Agreement and Schedules are being amended to reflect the expanded membership. The executive committee, led by JARI Director Tim Naish (VUW) and Deputy Director Richard Levy (GNS Science) are working on a revised strategic plan that reflects the partners' interests and objectives.

The ARC had a number of visiting academics during 2010, including:

Dr Robert Bindschadler, NASA, USA;
Professor Howard Conway, Earth and Space Science, University of Washington, USA;
Professor George Denton, University of Maine, USA;
Dr Ross Edwards, Curtin University of Technology, Australia;
Dr Stephen Eggins, Research Fellow, The Australian National University;
Dr Carlota Escutia Dotti, Instituto Andaluz de Ciencias de la Tierra, Spain;
Dr David Frame, Oxford University, UK;
Dr Mike Kaplan, Lamont-Doherty Earth Observatory, Columbia University, USA;
Franz Litz, World Resources Institute, Washington D.C., USA;
Professor Raymond Pierrehumbert, University of Chicago, USA;
Dr Hans Nelson, University of Granada, Spain;
Dr Frank Niessen, Alfred Wegener Institute, Germany;
Dr Frank Rack, ANDRILL Science Management Office, University of Nebraska-Lincoln, USA;
Professor Kendrick Taylor, Chief Scientist of WAIS, Desert Research Institute, USA;
Betty Trummel, ANDRILL Educator, USA;
Associate Professor Terry Wilson, Ohio State University, USA.

Staff and students within the ARC also worked closely with people from the following departments, organisations and institutes:

National Research Collaborators

- Antarctica New Zealand;
- Department of Geography, University of Otago;
- Department of Geology, University of Canterbury;
- Department of Geology, University of Otago;
- Department of Marine Science, University of Otago;
- Department of Physics, University of Otago;
- Gateway Antarctica, University of Canterbury;
- Geomarine Research Ltd.;
- GNS Science;
- NIWA;
- University of Auckland;
- University of Waikato.

National Stakeholders and End-users

- Antarctica New Zealand;
- Department of Conservation;
- Foundation for Research, Science and Technology;
- Land Information New Zealand;
- Ministry for the Environment;
- Ministry of Fisheries;
- Ministry of Foreign Affairs and Trade;
- Ministry of Research, Science and Technology;
- Royal Society of New Zealand.

Industry Partners

- Pro Machining;
- Webster Drilling & Exploration Ltd.;
- WekaStitch.

International Collaborators

- Alfred Wegener Institute, Germany;
- ANDRILL Science Management Office, University of Nebraska-Lincoln, USA;
- British Antarctic Survey, UK;
- Cambridge University, UK;
- Climate Change Institute, University of Maine, USA;
- Colgate University, USA;
- Curtin University of Technology, Australia;
- Desert Research Institute, USA
- ETH (Swiss Federal Institute of Technology), Switzerland;
- Harvard University, USA;
- Hamilton College USA;
- IDDO (Ice Drilling Design & Operations), University of Wisconsin, USA;
- INGV (National Institute of Geophysics and Volcanology), Italy;
- James Cook University, Australia;
- Lamont Doherty Earth Observatory, Columbia University, USA;
- Macquarie University, Australia;
- Moss Landing Marine Laboratories, USA;
- New Mexico Tech, USA;
- Northern Illinois University, USA;
- Centre for Climate and Ice, Niels Bohr Institute, University of Copenhagen, Denmark;
- Oregon State University, USA;
- Raytheon Polar Services Company, USA;
- Stanford University, USA;
- The Australian National University;
- The Pennsylvania State University, USA;
- University of California-Santa Barbara, USA;
- University of Chicago, USA;
- University of Delaware, USA;
- University of Kansas, USA;
- University of Leeds, UK;
- University of Massachusetts, USA;
- University of Milan, Italy;
- University of Oslo, Norway;
- University of Sienna, Italy;
- University of Tokyo, Japan;
- University of Victoria, British Columbia, Canada;
- University of Wales, UK;
- University of Washington, USA;
- Virginia Institute of Marine Sciences, USA;
- Woods Hole Oceanographic Institution, USA.

Contribution to International Programmes

- ANDRILL (Antarctic geological Drilling Program);
- ATHENA (Advancing Technological and Environmental Stewardship for Subglacial Exploration in Antarctica);
- IODP (Integrated Ocean Drilling Program);
- IPCC (Intergovernmental Panel on Climate Change;
- IPICS (International Partnership on Ice Coring Sciences);
- ITASE (International Trans-Antarctic Scientific Expedition);
- LGP (Latitudinal Gradient Programme);
- SCAR-ACE (Antarctic Climate Evolution);
- SCAR-AGCS (Antarctica in the Global Climate System).

Outreach

Staff, students and visitors at the ARC were involved in a variety of outreach activities during the year. These activities include interviews (newspapers, radio and television), talks to community groups, school visits and newsletters, and allow us to present our research and knowledge to the wider community both here and overseas.

Media (Newspapers, Radio, and Television)

* *TV3 News*: Andrew Mackintosh interview on Himalayan glaciers and IPCC report error, 19 January;
* *ABC Science Program Catalyst*, featuring Alice Doughty, Andrew Mackintosh, Brian Anderson, 1 April;
* *TV1 Breakfast*: Bob Bindschadler, 20 May;
* *The Press*: interview with Nancy Bertler, Alex Pyne, Ed Butler (Antarctica NZ), 22 May http://www.stuff.co.nz/the-press/lifestyle/3727000/Slice-of-ice;
* *Science Media Centre* "Science Alert – Experts Respond": Nancy Bertler a contributor, 28 May http://www.sciencemediacentre.co.nz/2010/05/28/will-the-southern-oceans-carbon-sink-hold-its-breath/;
* *BBC*: live public interview featuring Tim Naish on climate change and IPCC during Oslo IPY Conference, http://www.bbc.co.uk/news/10273566, 8 June;
* *The Press*: Tim Naish interview on sea-level rise, 15 June;
* *Nelson Mail*: Ice Drill, 16 June;
* *Science magazine news feature*: Tim Naish quotes on past sea-level reconstructions,. 1 July;
* More than 30 newspaper articles, online news reports, and radio interviews with Tim Naish during Australian Earth Sciences Conference, 5-8 July;
* *Antarctic Sun*: interview with Nancy Bertler on Roosevelt Island, 3 September;
* *AGU Climate Science Q&A Service for Journalists*: Nancy Bertler is an expert contributor, since September 2009;
* *New Zealand Listener*: Nick Golledge, 10 November;
* *Radio New Zealand*: Nick Golledge, 1 December;
* *International Cable Protection Committee*: Lionel Carter environmental updates for monthly newsletter
* Web-based presentation: Lionel Carter on cables receiving 66,814 downloads in past year http://www.iscpc.org/
* Feature film '*Earth*': Andrew Mackintosh is a consultant;
* *GNS Science pamphlet* on Te Wahi Pounamu World Heritage Area Fox and Franz Josef Glaciers: Brian Anderson;
* *ABC Canberra News*: featuring Naish on sea-level predictions and IPCC.

Public Talks, Events & Visits

* Public lecture: Lionel Carter, Victoria University, 6 January;
* Public panel discussion on Climate Change: Nancy Bertler with participants from VUW, GNS Science, NIWA, MfE, MoRST, and MFAT, Wellington, 29 January;
* Tales from Integrated Ocean Drilling Program (IODP) Presentation: Rob McKay, with Prof. Carlota Escutia (University of Granada, Spain), Victoria University, 16 March;
* Thailand Ministerial Delegation, Tim Naish, Peter Barrett, 18 March;
* Careers Advisers' Conference: Warren Dickinson, 25 March;
* Dialogues with Tomorrow, Downstage Theatre: Anne Noble (Massey University) and Peter Barrett, 15 April;
* Antarctica New Zealand Stakeholder function: invited presentation by Nancy Bertler, Wellington, 22 April;
* NZGS seminar series: Nick Golledge, Geography Department, Otago University, 22 April;
* Chinese Climate Change Ambassador, Tim Naish, 18 May;
* S.T. Lee Lecture in Antarctic Studies: invited presenter Dr Robert Bindschadler, (Hydrospheric and Biospheric Sciences Laboratory, NASA, USA), Victoria University, 19 May;
* Geoscience Society of New Zealand: Huw Horgan, Science House, 20 May;
* Wellington branch of University of the Third Age (U3A): Tim Naish, 21 May;
* Ambassador of the Federal Republic of Germany, Thomas Meister Visit: Nancy Bertler May;
* Marsden College Flexhibit Workshop: Betty Trummel (US ANDRILL Educator), Cliff Atkins (SGEES), Wellington June;
* Dyer St School, Lower Hutt: Dan Zwartz, 9 August;
* Hutt Valley Rock and Minerals Club: Tim Naish, 25 August;
* MARGINS Stakeholders Meeting: Lionel Carter, Te Papa, Wellington, 1 September;
* Inaugural Professorial Lecture: Lionel Carter, Victoria University, 14 September;
* Australasian Research Management Society: Tamsin Falconer, Wellington, 16 September;
* Science Media Centre Event: Dan Zwartz, Andrew Mackintosh, Tim Naish, 21 September http://www.royalsociety.org.nz/2010/09/21/new-paper-on-sea-level-rise/);
* Reflections on Colin Bull (1928-2010): Michael Hannah (SGEES) Peter Webb (Columbus, Ohio), Peter Barrett, Tim Naish and Andrew Mackintosh, Victoria University, 23 September;
* MoRST Spanish Research Council Delegation: Tim Naish, Rob McKay, Lionel Carter, 30 September;
* Geological Society Beanland-Thornley prize talk: Holly Winton, 7 October;
* Launch of Tara Arctic: A New Zealander's Epic Voyage by Grant Redvers, Museum of Wellington City & Sea: Tim Naish, 7 October;
* University of Waikato, invited graduation address: Tim Naish, 21 October;
* Marsden Outreach Programme: Gavin Dunbar, St. Bernards High School, 2 November;
* Institute of Professional Engineers NZ (IPENZ) Meeting: Lionel Carter, Wellington, 18 November;
* Post-graduate Certificate in Antarctic Studies: Lionel Carter, Gateway Antarctica, UCanterbury, 18 November;
* Test Screening of Thin Ice, AGU, San Francisco: 12 December.

Teachers workshop on ANDRILL educational materials (Photo: Betty Trummel)

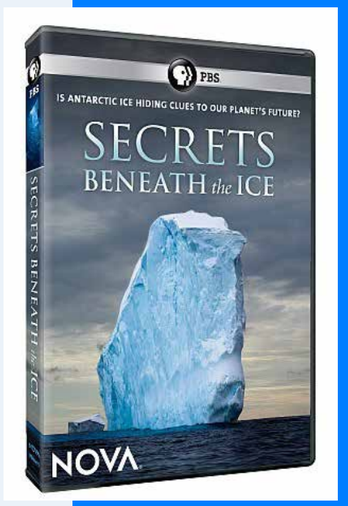
Outreach Reaches Nearly 4000 Downloads

Matthew Wood began a collaborative relationship with the ARC as a student, working as a field assistant on the Victoria Land Coast with Nancy Bertler in late 2003 and then received Master's supervision from Lionel Carter in the following years. After several years working in minerals exploration overseas, Matthew returned to New Zealand to pursue a new career in science communication. Teaming up with his friends and former-colleagues at the ARC, Matt launched "*Journeys to the Ice*", a podcast and blog featuring the recent science output of the ARC as well as other related university and community events. While often focussing on climate change research, the podcast also attempts to cover a broad range of Antarctic science. The podcast has reached a wide audience through distribution on iTunes and the Science Media Centre's Sciblogs website, with nearly 4000 downloads to date. While the podcast has mainly been presented as audio science interviews, Matthew is increasingly adding video content, including an upcoming multi-episode documentary of his recent travels in the sub-Antarctic islands aboard Heritage Expeditions' polar research vessel, *Spirit of Enderby*. "*Journeys to the Ice*" builds on the ARC's long tradition of educational outreach. To see the blogs visit: http://sciblogs.co.nz/journeystotheice/

Matthew Wood in the Subantarctic Islands (Photo: Jessica Kerr)

A juvenile elephant seal in the middle of the King penguin colony, Macquarie Island (Photo: Jessica Kerr)

ANDRILL Documentary on NOVA



A new documentary film featuring the ANDRILL Programme had its premier screening on US Public Television in late December. Five years in the making, "*Secrets beneath the Ice*" captures multinational research into Antarctica's past climate and features scientists, engineers, and drillers from New Zealand. The show was produced for US Public Broadcasting's NOVA series and is described on the premier science show's website as follows (http://wwwpbs.org/wgbh/nova/earth/secrets-beneath-ice.htm): "Almost three miles of ice buries most of Antarctica, cloaking a continent half again as large as the United States. But when an Antarctic ice shelf the size of Manhattan collapsed in less than a month in 2002, it shocked scientists and raised the alarming possibility that Antarctica may be headed for a meltdown. Even a 10 percent loss of Antarctica's ice would cause catastrophic flooding of coastal cities unlike any seen before in human history. What are the chances of a widespread melt? "*Secrets beneath the Ice*" explores whether Antarctica's climate past can offer clues to what may happen. NOVA follows a state-of-the-art expedition that is drilling three-quarters of a mile into the Antarctic seafloor. The drill is recovering rock cores that reveal intimate details of climate and fauna from a time in the distant past when the Earth was just a few degrees warmer than it is today. As researchers grapple with the harshest conditions on the planet, they discover astonishing new clues about Antarctica's past—clues that carry ominous implications for coastal cities around the globe." ARC staff, Tim Naish, Alex Pyne and Gavin Dunbar feature in this movie. Other New Zealand researchers include Richard Levy and Greg Browne (GNS Science).


IceSked

Issue 14: June 2010

Newsletter of the Antarctic Research Centre
Victoria University of Wellington

The year got off to a busy start with the port calls of two research vessels in January, in particular we highlight the expedition of the IODP Wilkes Land cruise. This issue also introduces two new staff, Dr's Dan Zwartz and Huw Horgan, who have recently joined our team, and we report on the research of three Masters students just completing their theses.

A Word From the Director

As this latest IceSked reaches you, the end of the International Polar Year (IPY) period will be marked by a major conference in Oslo, Norway where results from the many IPY science projects will be presented. Fifty years ago the previous IPY (and International Geophysical Year) led to a series of major advances in our understanding of Antarctica and its place in the global system. During this IPY many are asking, "will we see the same leap in our knowledge of the polar regions?" The answer must be undoubtedly yes, and the significance of this IPY is made even more poignant by the impact global warming is having, and will continue to have, on the polar regions. New satellite mass balance data, airborne geophysics, ice core and geological drilling records, combined with computer ice sheet and climate models are presently transforming our understanding of the behaviour and sensitivity of the Antarctic ice sheets. So as we reach the end of this IPY we face a

Research Centre staff and students feel privileged to have active

initiatives with our collaborators, and will continue to promote t

Sailing the Southern Ocean

Rob McKay, ARC Post-Doctoral Fellow, recently returned from a nine week long cruise aboard the JOIDES Resolution as part of the Integrated Ocean Drilling Program (IODP) scientific research expedition to drill sediment cores offshore from the Wilkes Land coastline, East Antarctica. The Resolution departed from Wellington, and during its port call ARC staff were involved in numerous outreach activities, including public science presentations, ship tours, and assisting with a summer school run by GNS Science for 12-15 year old students. Here's Rob's account of the trip.

My primary duty on the JOIDES Resolution was working with the sediment core description team during one of the 12-hour per day shifts. This team provided a description of the properties of the sediments and used this information to determine the environment in which the sediment was deposited, helping scientists decipher the past behaviour and stability of the East

Rob McKay at work describing

OFF THE ICE ON THE ICE

Supporting the Antarctic Research Centre

Wind Wave Dust

ANDRILL Coulman High Project Site Survey

Ice Core Drill Testing at 'NEEM' Greenland

Seasonal Sea Ice Dynamics

Roosevelt Island

ARC Newsletter - IceSked

The ARC continues to publish a twice-yearly newsletter for alumni, colleagues and stakeholders, which is distributed to over 400 recipients around the world. Issue 14, published in June, focussed on our younger researchers, profiling three MSc students, new Research Fellows Huw Horgan and Dan Zwartz, and Post Doctoral Fellow Rob McKay's IODP Wilkes Land experience.

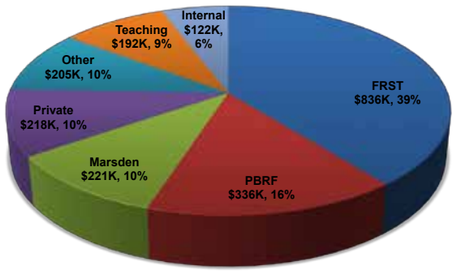
Issue 15, published in December, profiled the variety of work in the ARC, particularly the upcoming field season, and also gave some background on our glacial modelling research.

Finances

The Antarctic Research Centre received $2.13M revenue from three major sources: Research Grants (FRST, Marsden, private funds, internal grants and other); PBRF; and Teaching and Supervision within SGEES. Just over half of that income covers the costs associated with staff salaries (including salaries, annual leave, superannuation). The ARC actual revenue and expenditure for 2010 are summarized below (all figures are exclusive of GST).

At year end the ARC had a total of 21 externally funded research projects in operation, with a total balance of $94,000 surplus held by the Research Trust. Much of this balance is already allocated and relates to phasing of income versus expenditure; particularly over the University financial year end (December) which coincides with the Antarctic field season.

2010 Revenue Sources



FRST

- ANDRILL Programme, VUW portion of major grant to GNS Science, UOtago, UCanterbury, NIWA and VUW; one project completed Sept 2010, new grant started Oct 2010;
- ANZICE Programme, started October 2007 and runs through to Sept 2011;
- Regional Modelling, NIWA sub-contract until December 2011;
- Tasman Alps Glacier project, a GNS Science subcontract from April 2009 until September 2011;
- McKay Post-Doctoral Fellowship, from June 2009 to May 2012.

PBRF

- Calculated by VUW based on external research funding that meets the PBRF criteria, plus the quality rating of staff in the ARC. The ARC does not receive funding for research degree completions directly, as they are recorded within SGEES.

Marsden

- Dunbar FastStart, through to March 2010;
- New Naish Marsden ("*How Does Antarctica Ride the Milankovitch Cycle*") through to December 2012;
- Townend Marsden, supports work by Lionel Carter on this project.

Private Donations *(held by VUW Foundation)*

- Golledge Post-Doctoral Fellowship, funded from Alan Eggers donation until February 2012;
- Horgan Research Fellowship, funded from Alan Eggers donation until March 2011;
- Ice Core Drill development costs for testing in Greenland, funded from Alan Eggers donation;
- Morgan Family Charitable Foundation, support for Melissa Bowen and Dan Zwartz, from September 2009 until December 2011;
- Science Drilling Office, supported in part from the Alan Eggers Donation;
- ARC Endowed Development Fund, supported six students travel to conferences and courses in 2010.

Other

- Coulman High Project, funding from Antarctica New Zealand in support of a project plan and budget, and employment of field staff for the site survey;
- Science Drilling Office, funding from US ANDRILL Science Management Office to purchase items for the Hot Water Drilling site survey activities;
- International Cables Protection Committee, contract with Lionel Carter;
- Funding for travel to workshops/conferences – Mackintosh (MfE for IPCC workshop), Pyne (Ice Drilling workshop), McKay (SCAR conference), Naish (NIWA and IPCC for IPCC authorship meetings), Naish (IODP review travel);
- Funding from LINZ for support/maintenance of the Cape Roberts Tide Gauge;
- Sponsorship for Snow and Ice Research Group workshop from Antarctica New Zealand and Development West Coast;
- Funding from NIWA for research into Glass Eel Migration patterns;
- GNS Science contribution to Ocean Temperatures – Interglacial Stage project.

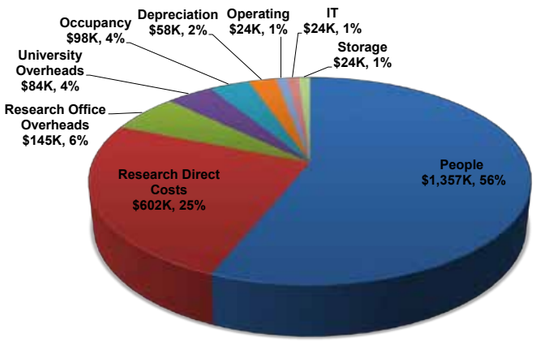
Teaching

- From SGEES for teaching services by ARC staff. Includes a sum for graduate completions not in previous years and a sum to cover costs of GPR equipment.

Internal

- Office of DVC-Research, sponsorship to support the production of the climate change film;
- Office of DVC-Research, contribution to the New Zealand membership to the Integrated Ocean Drilling Program;
- Internal grants from the Science Faculty, SGEES and the University Research Fund supported post graduate student conference and workshop travel, summer research assistance and time for completed graduate students to write up papers for publication.

2010 Expenditure



People

- Covers all salaries, ACC, annual leave, superannuation and other associated people costs.

Research Direct Costs

- Includes expenditure directly associated with research projects such as field work costs, conference attendance, analyses, and consumables. This category also includes pay for Research Assistants.

Research Office and University Overheads

- Used by the University for administrative purposes and to cover services provided by the Research Office and central University.

Occupancy

- Based on a charge per square metre for office and working spaces within the ARC.

Depreciation

- Covers the costs of CAPEX purchases.

Operating

- Includes costs involved in the daily running of the Centre such as printing and copying, catering, training, and kitchen supplies.

Storage

- Occupancy costs for storage spaces shared with SGEES.

Publications and Conferences

Scientific Journals (9)

Anderson, B., **Mackintosh**, A., Stumm, D., George, L., Kerr, T., Winter-Billington, A., Fitzsimons, S. 2010. Climate sensitivity of a high-precipitation glacier in New Zealand. *Journal of Glaciology* 56 (195): 114-128.

Davy, B., Pecher, I., Wood, R., **Carter**, L., Gohl, K. 2010. Gas escape features off New Zealand : Evidence of massive release of methane from hydrates. *Geophysical Research Letters* 37: L21309, doi:10.1029/2010GL045184, 2010

Fyke, J.G., Weaver, A.J., Pollard, D., Eby, M., **Carter**, L., **Mackintosh**, A., 2010. A new coupled ice sheet-climate model: Description and sensitivity to model physics under Eemian, Last Glacial Maximum, late Holocene and modern climate conditions. *Geoscientific Model Development* Discuss 3: 1223-1269, doi:10.5194/gmdd-3-1223-2010.

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Putnam, A.E., Denton, G.H., Schaefer, J.M., Barrell, D.J.A., Andersen, B.G., Finkel, R.C., Schwartz, R., **Doughty**, A.M. Kaplan, M.R., Schlüchter. C. 2010. Glacier advance in southern middle-latitudes during the Antarctic Cold Reversal., *Nature GeoScience* 3: 700-704. doi: 10.1038/NGEO962.

Sinclair, K.E., **Bertler**, N.A.N., and Trompetter, W.J. 2010. Synoptic controls on precipitation pathways and snow delivery to high-accumulation ice core sites in the Ross Sea region, Antarctica. *Journal of Geophysical Research* 115: D22112, doi:10.1029/2010JD014383.

Books/Book Chapters

Bertler, N.A.N. and **Barrett** P.J. 2010. Vanishing Ice Sheets. In Dodson, J. (ed), Changing Climates, Earth Systems, and Society. Springer, 1st Edition., 360 p., ISBN: 978-90-481-8715-7

Theses

Mearns, R., 2010. Marine palynomorphs from the Plio- Pleistocene interval of the AND-1B Drill-Core McMurdo Sound, Antarctica. Unpublished MSc Thesis, Victoria University of Wellington, Wellington. 188pp.

O'Donnell, R., 2010. Modelling Quaternary glacier extent and climate in Tasmania, Australia. Unpublished MSc Thesis, Victoria University of Wellington, Wellington. 127pp.

Purdie, H., 2010. Controls on Spatial and Temporal Variation in Snow Accumulation on Glaciers in the Southern Alps, New Zealand. Unpublished PhD Thesis, Victoria University of Wellington, Wellington.

Ryan., M.T., 2010. A palynological record of the vegetation and climate of Westland since 210 ka. Unpublished MSc Thesis, Victoria University of Wellington, Wellington.

Stevens, M., 2010. Miocene and Pliocene silicic Coromandel Volcanic Zone tephras from ODP Site 1124-C: Petrogenetic applications and temporal evolution. 144pp.

van de Ven, E., 2010. Sedimentology and zircon geochronology of the CIROS-1 drill core, Ross Sea, Antarctica". Unpublished MSc Thesis, Victoria University of Wellington, Wellington.

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Bertler, N.A.N., 2010. Immediate Science Report – K049 *New Zealand ITASE*, 12p.

Bowen, M.M., Jellyman, D., 2010. Is variability in New Zealand glass eel recruitments and elver catches determined by the physical environment?, *Report prepared for NIWA subcontract to VUW*.

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Falconer, T.R. and **Pyne**, A.R., 2010. ANDRILL Coulman High Project Plan and Budget, Version 1.1 July 2010. *Unpublished report, Wellington, Antarctic Research Centre*, Victoria University of Wellington, 49pp.

Mackintosh, A., **Naish**, T., and **Zwartz**, D., 2010. *Royal Society 'Emerging Issues' statement on sea-level rise*. http://www.royalsociety.org.nz/2010/09/21/new-paper-on-sea-level-rise/)

Conference Proceedings

Dickinson, W.W., Schiller, M., Ditchburn, R.G., Graham, I.J., Zondervan, A., 2010. Soil indicators of paleoclimate in the Dry Valleys, Antarctica. *Geological Society of America Abstracts with Programs* 42(5): p.231.

Conference – Session/Theme Convenor

Naish, T., and **Mackintosh**, A., Antarctic deglaciations: Mechanisms, timing and character. *SCAR Open Science Meeting*, Buenos Aires, Argentina, 3-6 August 2010.

Naish, T.R., Brigham Grette, J., Sime, L., Climate and paleoclimate dynamics and processes. *IPY Oslo Science Conference*, Oslo, Norway, 8-12 June 2010.

Conference – Invited Oral Presentations

Mackintosh, A., 2010. Mechanism and timing of East Antarctic ice sheet recession. *IPCC ice sheets and sea level Meeting*, Kuala Lumpur, Malaysia, 21-24 June 2010.

Mackintosh, A., **Anderson**, B., **Golledge**, N., **O'Donnell**, R., Pierrehumbert, R., Hubbard, A., Newnham, R., 2010. Glacial modelling in the mid latitudes of the Southern Hemisphere and PMIP2 models. *PMIP3 Workshop*, Kyoto, Japan. 6-10 December 2010.

Naish T., 2010. Antarctic and Southern Ocean Influences on Late Pliocene Cooling (Keynote address). *Australian Earth Sciences Conference*, Canberra, Australia, 5-8 July, 2010.

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Alley, R.B.; Anandakrishnan, S.; Parizek, B.R.; Walker, R.T.; **Horgan**, H.J., 2010. The bumpy path to grounding-line (in)stability—past, present and future. *American Geophysical Meeting Fall Meeting*, San Francisco. USA, 13-17 December 2010. abstract #C51B-02

Anderson, B., and **Mackintosh**, A., 2010. Present-day fluctuations of glaciers in the Southern Alps, New Zealand, and their climatic drivers. *International Glaciological Conference Ice and Climate Change: A View from the South*, Valdivia, Chile, 1-3 February 2010.

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Bowen, M.M., 2010. Flow in the Antarctic Circumpolar Current along the Campbell Plateau responds to South Pacific winds. *New Zealand Marine Science Society 50th Anniversary Conference*, Wellington, New Zealand, 5 July 2010.

Carter, L., 2010. Perspectives on global change from beneath the ocean floor. *New Zealand's Legacy of Ocean Drilling Meeting*, Victoria University of Wellington, New Zealand, 6 January 2010.

Carter, L., 2010. Marine Environmental Advisors Report 2010. *ICPC Plenary*, Mauritius, 1-3 June 2010.

Carter, L., and **Gavey**, R., 2010. Three disruptions and an analysis Southern Taiwan, 2006-2010. *ICPC Plenary*, Mauritius, 1-3 June 2010.

Carter, L., **Dunbar**, G., Duncan, B., de Conto, R, **Naish**, T., Bostock, H., 2010. Southern ice and ocean change during marine isotope stage 7. *SCAR Open Science Meeting*, Buenos Aires, Argentina, 3-6 August 2010.

Carter, L. Gomez, B., Orpin A., & the Tutira Past Climate Group, 2010. Antarctic forcing of New Zealand's Climate. *Annual Antarctic Conference - A Taste of the Ice*, Christchurch, New Zealand, 5-7 July 2010.

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Doughty, A., **Mackintosh**, A., **Anderson**, B., Putnam, A., Kaplan, M., Denton, G., Schaefer, J., Barrell, D., Andersen, B., Kees, L. 2010. Using glacier models to reconstruct climate change over the last 13,000 years. *New Zealand International Glaciological Society Branch Meeting*, Queenstown, New Zealand, 15-17 February 2010.

Duncan, B., **Carter**, L., **Dunbar**, G., 2010. Marine isotope stage 7 – ocean response to a warmer world. *New Zealand Geological Society Annual Conference*, Auckland, New Zealand, 22-24 November 2010.

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Kolodziej. A., 2010. Planktic foraminifera-based sea surface temperature estimates and late Quaternary oceanography off New Zealand's west coast. *New Zealand Geological Society Annual Conference*, Auckland, New Zealand, 22-24 November 2010.

Mackintosh, A., **Golledge**, N., Domack, E., Dunbar, R., Leventer, A., White, D., Pollard, D., DeConto, D., Fink, D., Gore, D., Lavoie, C. 2010 Mechanism and timing of East Antarctic ice sheet recession. *SCAR Open Science Workshop*, Buenos Aires, Argentina, 3-6 August 2010.

McKay, R., **Naish**, T., **Carter**, L., Riesselman, C., Sjunneskog, C., Winter, D., Dunbar, R., Levy, R., Scherer, R., Powell, R., 2010. Antarctic and Southern Ocean influences in global Late Pliocene cooling. *American Geophysical Meeting Fall Meeting*, San Francisco. USA, 13-17 December 2010.

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Plant, A.A., Baker, J.A., **Carter**, L., Graham, I., Handler, M.R. Ulfbeck, D.G. 2010. Long-lived isotopes: tracking changes in paleo-ocean circulation and ice sheet dynamics of the Antarctic-Southern ocean system. *New Zealand Geological Society Annual Conference*, Auckland, New Zealand, 22-24 November 2010.

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Wilson, G.S., Levy, R.H., **Naish**, T.R., Powell, R.D., Henrys, S.A., Ross, J.I., 2010. Neogene tectonic and climatic evolution of the western Ross Sea – chronology of events from the AND—1B drillhole. *IPY Oslo Science Conference*, Oslo, Norway, 8-12 June 2010.

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Atkins, C.B., and **Dunbar**, G. 2010. Quantifying aeolian sediment and Iron flux, phytoplankton blooms and sedimentation in McMurdo Sound, Antarctica. *ANDRILL SMS Workshop*, Erice, Sicily, 6-11 April 2010.

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Joy, K., **Atkins**, C., Storey, B., Fink, D., 2010. The Darwin/Hatherton glacial system: Preliminary results of geomorphological mapping and cosmogenic sampling in 2009/10. *Annual Antarctic Conference - A Taste of the Ice*, Christchurch, New Zealand, 5-7 July 2010.

Markle, B., **Bertler**, N.A.N., Baker, J., Sinclair, K., Sneed, S., 2010. Climate record from a coastal ice core, Gawn Ice Piedmont, Ross Sea Region, Antarctica. *Annual Antarctic Conference – A Taste of the Ice*, Christchurch, New Zealand, 5-7 July 2010.

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Sinclair, K.E., and **Bertler**, N.A.N., 2010. Mechanisms for moisture delivery to two ice core sites in the Ross Sea region, Antarctica. *International Polar Year Oslo Science Conference*, Oslo, Norway, 8–12 June 2010.

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Winton, H., **Bertler**, N.A.N., **Dunbar**, G., Delmonte, B., 2010. Aeolian Dust Variability in McMurdo Sound, Antarctica. *Annual Antarctic Conference – A Taste of the Ice*, Christchurch, New Zealand, 5-7 July 2010.

List of Acronyms

ACE	Antarctic Climate Evolution (SCAR programme)
AGCS	Antarctica in the Global Climate System (SCAR programme)
AGU	American Geophysical Union
ANDRILL	ANtarctic geological DRILLing
ANZICE	Antarctica-New Zealand Interglacial Climate Extremes (ARC FRST-funded programme)
ANTscape	A research initiative focused on the paleogeography and paleoelevation of Antarctica from Cretaceous to Present time
AOMG	ANDRILL Operations Managment Group
ARC	Antarctic Research Centre
ATHENA	Advancing Technological and Environmental Stewardship for Subglacial Exploration in Antarctica
CIROS	Cenozoic Investigations of the western Ross Sea
EAIS	East Antarctic Ice Sheet
ENSO	El-Nino Southern Oscillation
EPICA	European Project for Ice Coring in Antarctica
ESCI	Earth Science (a Victoria University course code)
ETH	Swiss Federal Institute of Technology
FRST	Foundation for Research, Science and Technology
FTE	Fulltime Equivalent
GEOG	Geography (a Victoria University course code)
GNS Science	Institute of Geological and Nuclear Sciences Ltd.
GPR	Ground Penetrating Radar
GPS	Global Positioning System
IARC	International Arctic Research Center (University of Alaska Fairbanks)
ICDP	Inter-Continental Drilling Programme
IDDO	Ice Drilling Design & Operations (University of Wisconsin)
INGV	National Institute of Geophysics and Volcanology (Italy)
IODP	Integrated Ocean Drilling Program
IPCC	Intergovernmental Panel on Climate Change
IPICS	International Partnership on Ice Coring Sciences
IPENZ	Institute of Professional Engineers of New Zealand
IPY	International Polar Year
ITASE	International Trans Antarctic Scientific Expedition (ice coring collaboration)
IUGS	International Union of Geological Science
IYPE	International Year of Planet Earth
JARI	Joint Antarctic Research Institute
JOIDES	Joint Oceanographic Institutions for Deep Earth Sampling
LINZ	Land Information New Zealand
LGM	Last Glacial Maximum
LGP	Latitudinal Gradient Programme
MFAT	Ministry of Foreign Affairs and Trade
MfE	Ministry for the Environment
MIS	McMurdo Ice Shelf (ANDRILL drill site)
MoRST	Ministry of Research Science and Technology
NEEM	North Greenland Eemian Ice Drilling (University of Copenhagen, Denmark project)
NIWA	National Institute of Water and Atmospheric Research
NSF OPP	National Science Foundation (US science funder) Office of Polar Programs
NZGS	New Zealand Geographical Society

ODP	Ocean Drilling Program
OSU	Ohio State University
PBRF	Performance Based Research Fund
PHYG	Physical Geography (a Victoria University course code)
PISM	Parallel Ice Sheet Model
RICE	Roosevelt Island Climate Evolution (ice coring project)
SAM	Southern Annular Mode
SCAR	Scientific Committee on Antarctic Research
SDO	Science Drilling Office
SGEES	School of Geography, Environment and Earth Sciences
U3A	University of the Third Age (retired members organisation)
UAF	University of Alaska-Fairbanks
UCanterbury	University of Canterbury
UN	United Nations
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UOtago	University of Otago
UVic	University of Victoria, Canada
UWales	University of Wales
VUW	Victoria University of Wellington
WAIS	West Antarctic Ice Sheet

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