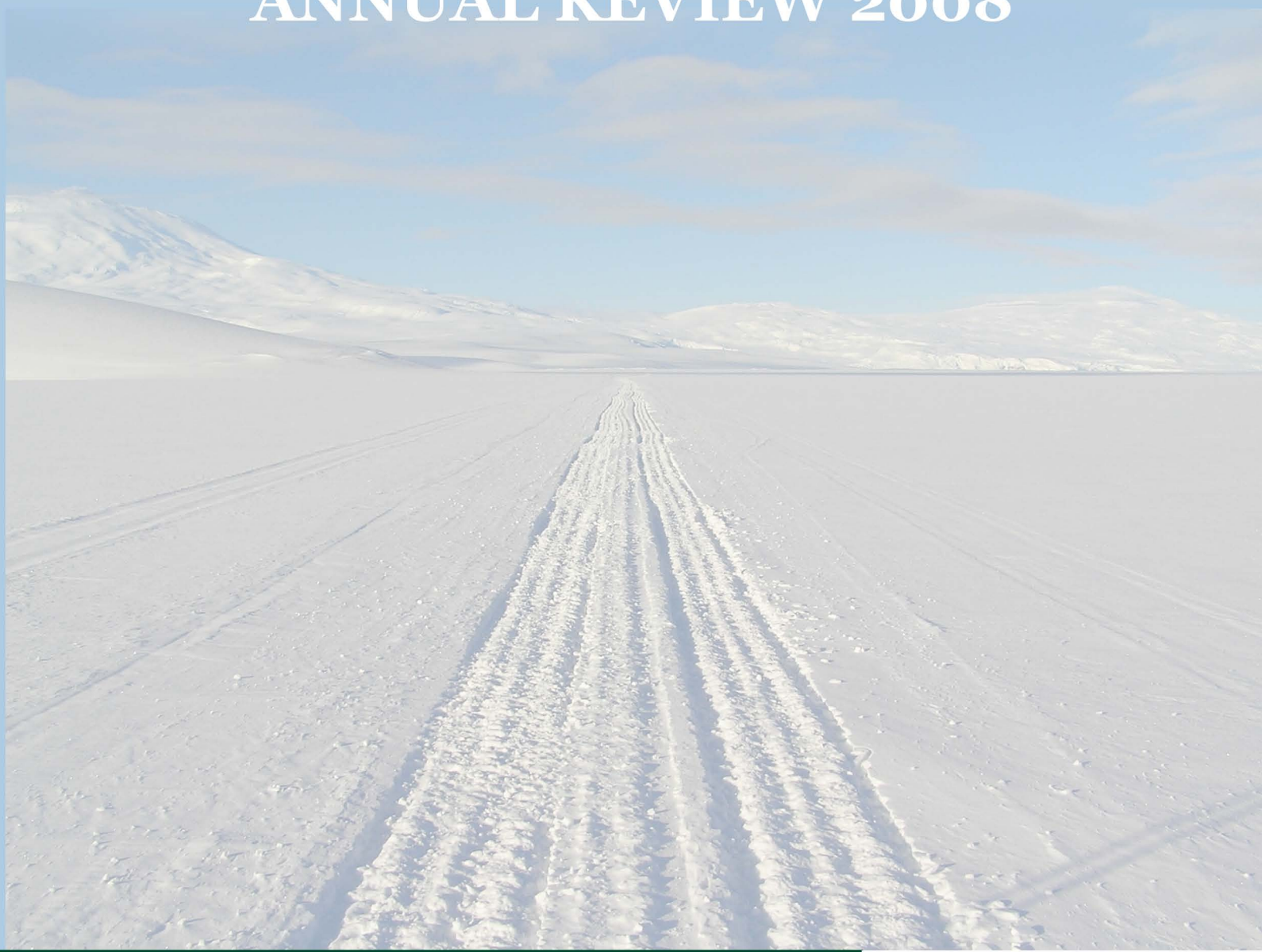
ANTARCTIC RESEARCH CENTRE
VICTORIA UNIVERSITY OF WELLINGTON

ANNUAL REVIEW 2008



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

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REPORT FOR 2008, WITH OUTLINE FOR 2009 AND BEYOND

1. SUMMARY

The last 7 years has seen dramatic growth in staff, budget and demand for space within the Antarctic Research Centre (ARC). We currently have 7.9 FTE research staff (including a new engineer and glacier modeling post-doc), 0.25 FTE Communications Fellow, 1.0 FTE Projects Manager, 1.8 FTE Centre Manager and Administrator, and 11 PhD and MSc students. Our annual operating budget is ~$1M with another ~$2M sitting in Research Trust and VUW Foundation accounts. We have reached a critical mass where we are now able to sustain output of a body of high quality science and publications spanning ice core (atmospheric), continental margin (ice sheet) and oceanic paleoclimatology integrated with numerical modeling of ice sheets, glaciers and global climate. Our ability to recover key ice core and marginal Antarctic geological records is enhanced by our world class polar drilling capability in the Science Drilling Office (SDO) together with logistical support from Antarctica New Zealand. This has enabled VUW-ARC and New Zealand maintain its leadership in international collaborative paleoclimate drilling initiatives.

In 2008 ARC staff led the delivery of new ANDRILL science results from the first McMurdo Ice Shelf hole at several international meetings (eg. AGU, EGU, WAIS Initiative), and the development of several high-profile publications now accepted in international journals (e.g. Nature, GSA Bulletin), and contributed to the Initial Science Results volume of the Southern McMurdo Sound hole, as well as working to secure substantial new funding for further international Antarctic paleoclimate research. New results document the pattern of behaviour of the West Antarctic Ice Sheet/Ross Ice Shelf and controls on its mass balance during the Pliocene warm period, 4 million years ago when atmospheric CO_2 was 400ppm and surface temperatures 2-5°C greater than today.

The ice coring programme continued with field surveys prior to next season's drilling at either Roosevelt Island or in the Darwin Glacier region, and the National Ice Core Facility became fully operational, with a crop of new students beginning and a number completing thesis research. With support from the Eggers Fund, VUW has contributed to the new New Zealand-Australia membership in the Integrated Ocean Drilling Program, and has secured a role for Dr Rob McKay as shipboard sedimentologist on the forthcoming expedition to the Wilkes Margin (Jan 2010).

Research into our less distant past climate (the last 1 million years) in the Antarctic-New Zealand Interglacial Climatic Extremes (ANZICE) programme is already producing exciting results using innovative geochemical analyses of marine microfossils to determine changes on ocean-climate off eastern New Zealand and its relationship to Antarctic-Southern Ocean influences. Initial results from more than 4000 snow and ice analyses are tracking variability in air temperature, sea-ice extent, atmospheric circulation through the Little Ice Age and Medieval Warm Period in McMurdo Sound. This unique Antarctic record of historic warming will provide an important analogue of future change. Research into the Southern Alps glaciers continues to develop models that relate regional climate variables to mass balance (the balance between snow accumulation and melt). Through a new collaboration with NIWA, the model is being coupled to a glacier flow model to calculate catchment melt and run-off to South Island lakes. Finally an intermediate complexity ocean-atmosphere global climate model has been applied to simulate the behaviour of ice shelves to atmospheric warming in the Antarctic Peninsula (e.g. the Larsen and the Wilkins).

The SDO has now been operating as an entity within ARC for a year with improved brand recognition of our distinctive capability in polar drilling technology and management. This has led to new contracts for ANDRILL and consulting for the Intercontinental Drilling Program. SDO staff are actively working with international and national stakeholders (eg. NSF, Antarctica New Zealand, ANDRILL Science Management Office) on the requirements and planning for future Antarctic drilling projects and proposals, while ARC scientists are working with the international community to prioritise future paleoclimate research objectives in Antarctica and develop co-ordinated international proposal pressure.

The ARC continued to grow in 2008 with the appointment of new staff and adjustments to some existing staff contracts: (i) Andrew Mackintosh at 0.5 FTE shared with School of Geography, Environmental and Earth Sciences (SGEES), (ii) Brian Anderson as a 0.67 FTE research fellow in glacial modelling, (iii) Robert McKay as a FRST-Post Doctoral Research Fellow, (iv) Michelle Dow increased to a 0.8 FTE Administrator. (v) Darcy Mandeno as a new engineer in the SDO, and (vi) Nick Golledge as an Eggers-funded Research Fellow in glacial modeling. Both Darcy and Nick start in March 2009. We currently have 11 post graduate students with plans to bring on another 3 or 4 in 2009 as well a Post-Doctoral Research Fellow in glacial geophysics. This has put increased pressure on space and resources. Two Antarctic-related Marsden applications are pending in 2009 and discussions have begun on future Antarctic paleoclimate research funding with FRST. The ARC came in under budget last year and has a responsible, yet flexible budget, for the coming year.

2009 promises to be an exciting year. As Tim Naish embarks on his second year as ARC Director he will run a strategic planning process in order to more effectively manage and plan for Centre activities over the next 5 years. ANDRILL and ANZICE will deliver fundamental policy relevant new research results, the ice drill will be completed, ANDRILL will plan for the Coulman High Project, the IODP Wilkes Land drilling leg will gear up, a major ice drilling field season in Antarctica is being planned for the end of the year, the Antarctic climate community will gather at a major meeting sponsored by the SCAR Antarctic Climate Evolution project in Grenada Spain, and finally we anticipate a constant stream of visiting researchers to keep us stimulated and current.

2. MISSION AND WORK OF THE ANTARCTIC RESEARCH CENTRE

In July of 2004, the Advisory Board adopted the following as the Mission of the Antarctic Research Centre:

> Research the field of Antarctic earth sciences with a focus on past climate history and processes and their influence on NZ and global climate, and as a consequence:
> - Provide University teaching services related to the Centre's research
> - Advise the government on Antarctic issues as requested
> - Promote the study of the Antarctic and its value to society

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

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The current research programme includes two FRST Programmes:
i) ANDRILL - Antarctic climate history of the last 25 million years extracted from sediment cores from the Antarctic margin, and related on-land studies in the McMurdo Dry Valleys

ii) ANZICE - **A**ntarctic-**N**ew **Z**ealand **I**nterglacial **C**limate **E**xtremes in the geologically recent past. Objectives are

i) Ocean history from sediment cores in the Antarctic-New Zealand region
ii) Antarctic ice core climatology, and
iii) Ice and climate modeling

All three ANZICE objectives have further connections to other related projects, e.g. the US MARGINS program, the GNS Science GCT programme and the Comer Foundation's work in New Zealand.

The ARC mission is to improve understanding of Antarctic climate history and processes and their influence on the global climate system, especially New Zealand and the SW Pacific region. We believe this field provides exciting opportunities and challenges attractive to young researchers, and is needed to provide a sound basis for international debate and policy development on global change issues.

3. ANTARCTIC RESEARCH CENTRE ADVISORY BOARD

The Antarctic Research Centre Advisory Board, met twice during 2008 to advise on the strategic direction of the Centre and its performance.

The terms of reference for the Board are to:
i) Advise on the medium-long term strategic direction of ARC research;
ii) Advise on the direction of current research activities;
iii) Provide comment to the PVC and Director on the overall performance of the ARC;
iv) Provide comment to the PVC and Director on the overall operations of the ARC including finances and links with other institutions.

The Board members for 2008 were:
Dean of Science, VUW – David Bibby (convener)
Head of School of Geography, Environment and Earth Sciences – Mike Hannah
Director, Antarctic Research Centre – Tim Naish
Manager, Research & Commercial, VUW – Ian McIntosh
MFAT Antarctic Policy Unit – Trevor Hughes/Sandra Pope
FRST representative – Ruth Berry
MoRST representative – Tony Robinson
CEO, GNS Science – Alex Malahoff
General Manager: Research, GNS Science – Robin Falconer
CEO, AntarcticaNZ – Lou Sanson
Research Manager, NIWA – Rob Murdoch
Gateway Antarctica representative – Wendy Lawson

4. ANTARCTIC STUDIES AT VUW AND THE ANTARCTIC RESEARCH CENTRE

Academics at VUW represent a wide range of interests in the Antarctic region from tourism and law to literature and politics (see Table 1). There is also significant research in Antarctic biology and the properties of ice. The longest-standing group however is centered in the field of Earth Sciences, and has sent expeditions to the ice annually since the International Geophysical Year (IGY-1957). This group was set up as an Antarctic Research Centre in the early 1970's, and is the subject of this report. Current staff and

associates are listed in Table 1 along with other University staff with Antarctic interests and expertise.

Table 1 VUW staff and students with significant Antarctic interest and expertise in 2008.

Antarctic Research Centre	**Main Antarctic interest**
Tim Naish, Director (0.8)	Cyclostratigraphy, Palaeoclimatology
Brian Anderson, Research Fellow (0.67)	Glacial modelling
Peter Barrett, Professor of Geology (0.7)	Stratigraphy, Antarctic climate history
Nancy Bertler, Senior Research Fellow (0.5)	Ice core climatology
Lionel Carter, Professor in Marine Geology (0.7)	Marine geology
Warren Dickinson, Senior Research Fellow (0.2)	Sedimentary petrology and permafrost
Michelle Dow, Administrator (0.8 since June)	Paleontology and climate change
Gavin Dunbar, Research Fellow	Marine geology
Tamsin Falconer, Centre Manager	Sea ice, drilling, Antarctic history and art
Mike Hannah, Associate Professor in Geology (0.2)	Marine palynology and biostratigraphy
Simon Lamb, Senior Fellow in Science Communication (0.25)	Climate change, science communication
Andrew Mackintosh, Snr Lecturer in Geol/Geog (0.5 since June)	Glacial geology and glacial modelling
Rob McKay, Post-Doctoral Fellow (since October)	Sedimentology
Alex Pyne, Projects Manager	Antarctic logistics and drilling technology
VUW staff with Antarctic interests and expertise	
Cliff Atkins, Lecturer in Geology	Sedimentary processes and environments
Paul Callaghan, Professor of Physics	Properties of sea ice
Simon Davy, Snr Lecturer in School of Biological Sciences	Marine symbiosis
Roy Fleetwood, Professor of Design	Design of remote field camps
Margaret Harper, Research Assoc in Geology	Freshwater algae
Bill Manhire, Professor of English	Antarctic literature
Mark McGuinness, Assoc Professor of Mathematics	Modeling
Joanna Mossop, Lecturer in Law	International law
Ronan O'Toole, Lecturer in Microbiology	Environmental microbiology
Peter Ritchie, Snr Lecturer in School of Biological Sciences	Evolutionary genetics
Nigel Roberts, Assoc Professor of Political Science	Antarctic politics and history
Ken Ryan, Res Fellow in School of Biological Sciences	Marine algae
Tim Stern, Assoc Professor in Geophysics	Solid earth geophysics, 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, Snr Lecturer in Business & Public Mgmt	Antarctic environmental issues

Research students and projects

Annette Bolton, PhD in Paleoceanography – Using interglacial periods for understanding Holocene and future climate change.

Rosie Cody, PhD in Biochronology & Biostratigraphy – Paleoenvironmental evolution of ocean/climate systems in the SW Pacific.

Jeremy Fyke, PhD in Ice/Ocean Modelling – Modelling the sensitivity of the Antarctic ice/ocean system to climate change.

Rob McKay, PhD in Sedimentology – A sediment model for beneath the McMurdo Ice Shelf (completed July 2008).

Heather Purdie, PhD in Glaciology and Climatology – Relations between snow accumulation, climate and circulation, NZ

Rachael Rhodes, PhD in Ice Core Climatology – Ice trace element variability to reconstruct atmospheric circulation.

Julia Bull, MSc in Geology – Trace element chemistry of Antarctic snow as a record of past climate.

Julene Marr, MSc in Geology – Changes in NZ sea-surface temperatures during last deglaciation.

Rory Mearns, MSc in Geology – Marine palynology of the McMurdo Ice Shelf Late Cenozoic drill core.

Matt Ryan, MSc in Geology – Late Quaternary climates of Westland: A comparison between marine and terrestrial proxies.

Evelien van de Ven, MSc in Geology – Growth and evolution of the Antarctic continent from zircon geochemistry and geochronology.

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5. SCIENTIFIC ACTIVITY IN 2008

i) ANDRILL - coring Antarctic strata for climate history (www.andrill.org)

The ANDRILL Program has had a purple year in 2008 as it moves into the data analysis and publication stage in both the McMurdo Ice Shelf and the Southern McMurdo Sound projects.

Scientific highlights:

- Best physical records to date of Antarctic climate history of the past 25 million years.
- Provides fundamental new insights into the sensitivity of the West Antarctic ice Sheet.
- Indicates a dynamic Ross Ice Shelf and West Antarctic Ice Sheet regularly fluctuating between ice free open ocean conditions and a grounded ice sheet in response to orbital forcing between 5-3 million years ago, when atmospheric CO2 was about 400 ppm (like today) yet the Earths surface temperatures were 3-4°C warmer.
- The results are in press in *Nature* in the form of two papers: (1) Naish et al. *"Obliquity-paced Pliocene West Antarctic Ice Sheet oscillations"*, which presents the physical evidence from the drillcore record. (2) Pollard et al. *"Modelling West Antarctic ice Sheet growth and collapse through the last 5 million years"*, which presents a new ice sheet model verified by the drill core record). We have been invited to submit images to be considered for the cover and expect a news and views to be written. Publication is likely to be in late March.
- Potential to quantify sea-surface temperatures that led to past ice shelf/ice sheet retreat/collapse, using a paleothermometer that relates the chemical composition of the shells of microplankton to the temperature of the water they once lived in. This work, being led by Gavin Dunbar, is well underway and should be published in 2009.
- Publication of an overview paper on the results of the MIS project in the plenary volume (book in the National Academies Press) from the 10th International Symposium on Antarctic Earth Sciences.
- Publication of a new book in the Elsevier Developments in Earth and Environmental Sciences series, No *8 "Antarctic climate Evolution"*. ARC staff co-authored 5 chapters and lead authored 3 of the chapters. This book represents the present understanding of Antarctica's Cenozoic (climate evolution using numerical modelling results integrated with geological data.
- ANDRILL also had feature news articles in Terra Antartica, EOS, GeoTimes, Science, Scientific Drilling, Nature and Pages news.
- ARC staff also co-authored 7 papers in a special issue on Antarctic Cryosphere and Southern Ocean Climate Evolution in *Palaeogeography, Palaeoclimatology, Palaeoecology (5 FRST-ANDRILL, 2 FRST-ANZICE)*

- Acceptance of a paper in Geological Society of America Bulletin by McKay et al. on the long-term evolution of the WAIS from a warm mobile feature in the Pliocene to its present cold polar state examining some of the key controls on its mass balance.

West Antarctic Ice Sheet Initiative

ANDRILL MIS Project convened a session on Antarctic paleoclimate records at the annual meeting of the WAIS Initiative in Washington DC in October. WAIS brings together glaciologists, modellers, and process geologists in order to better understand the behaviour of WAIS. They are co-ordinating a community ice sheet model to provide an accurate prediction of WAIS contribution to the upper bound of sea-level rise for IPCC AR5. The integration of geological records of past behaviour such as ANDRILL is key to achieving this outcome.

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Antarctic Climate Evolution Session at the Fall American Geophysical Union meeting
Tim Naish (NZ), Ross Powell (US), Fabio Florindo (IT), David Harwood (US) and Richard Levy (NZ) convened two oral and one poster sessions on Antarctic Climate Evolution where innovative new results from ANDRILL, numerical modelling and paleoceanography communities were presented. Again the highlight was seeing the new insights from integrating geological proxy data with numerical climate and ice sheet models.

ANDRILL FRST Review
The Foundation of Research Science and Technology's investment in the ANDRILL Programme was reviewed in the first week of April by an international panel chaired by Dr John Hay and included Prof Nicholas McCave (Uni Cambridge), Prof Thomas Crowley (Uni Endinburgh), Dr Will Howard (Uni Hobart and Antarctic Climate and Ecology CRC). Over three days of presentations, expert witnesses and discussions the programmes performance was assessed in the areas of Management and Leadership, Research/Science Quality, Technical Capability, Education and Outreach, and Economic Benefits. The panel provided a comprehensive report awarding a 5 out of 5 (Very Strong Performance). The review was initiated by the science providers with the FRST in order to initiate a process of planning for future Antarctic drilling related science.

Coulman High Drilling Project and future planning
Given the rate at which the Antarctic cryosphere is responding to global warming and the lack of certainty surrounding the dynamic ice sheet contribution to sea-level rise articulated in IPCC AR4, future research is being prioritised at the international level within the WAIS Initiative and ice sheet modelling communities, remote sensing communities (satellite data, NASA, ESA), and paleoclimate communities (eg. SCAR, ANDRILL, SHALDRIL, IODP, EPICA). The ARC are closely engaged with these paleoclimate groups planning a strategy that targets past records of the most vulnerable sectors of both the WAIS and EAIS. New Zealand's research and potential operational contribution to this effort will be outlined in a "white paper" to FRST and Antarctica New Zealand in early 2009. Presently a proposal to drill a record of WAIS and EAIS past behaviour on the fast-flowing edge of the Ross Ice Shelf is being assessed by NSF. While this is a US proposal NZ contributed to its development and indicated research areas that NZ scientists were interested in. Both NSF, ANTNZ and FRST are communicating as this proposal is assessed. A EuroANDRILL proposal to the European Polar Board to participate in ANDRILL Coulman High and beyond involving more than a dozen countries has reached the full proposal, second round stage.

NOVA ANDRILL Documentary
A PBS-NOVA collaboration in the US with NSF IPY funding support has been making a documentary over the last 4 years following the ANDRILL MIS project from inception, site surveys, drilling to results and publication. Recently they were in New Zealand filming the geological evidence preserved in Wanganui Basin of Antarctic-forced sea-level changes when temperatures were warmer than today in the Pliocene (4 Ma). Unwittingly Tim Naish has become the central character in this film which is due for release in November 2009.

ii) ANZICE - Antarctica New Zealand Interglacial Climate Extremes programme
Although just 15 months into the programme, the FRST-funded **A**ntarctic **N**ew **Z**ealand **I**nterglacial **C**limatic **E**xtremes or ANZICE has made substantial progress into reconstructing environmental responses of the NZ-Antarctic region to past warm extremes as analogues for models of future change.

As with any new programme, the initial phase involves the collection of samples, analysis and data generation and model development analysis. In that context, the Antarctic objective has concentrated on the collection of snow pit samples and ice cores that have been prepared and analysed for a wide range of geochemical proxies at [i] the ICP mass spectrometry laboratory at VUW, [ii] the ice core facility at GNS Science and [iii] the University of Maine. Some highlights:

- Over 4000 samples from snow sections and ice cores have been analysed for isotopes and geochemical elements. These indicators of change are providing information on the age of the snow/ice, air temperature, degree of windiness, extent of sea ice and ocean turbulence. Preliminary results have identified the Little Ice Age, a cold spell from 1400 to 1850 AD mostly found in Northern Hemispheric records, when temperatures were ~1^{o}C cooler than today. The record also

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identified potentially the termination of the Mediaeval Warm Period (800-1400 AD) when temperatures were 1 to 2^{o}C warmer and storms more prevalent than now.

- Using proxies for marine aerosols and phytoplankton production derived from snow pit samples from Mt Erebus, it has been demonstrated that concentrations of these proxies reduce during years of exceptional sea ice such as accompanied the blocking of McMurdo Sound by the giant icebergs B15 and C19. The proxy signatures will be applied to ice cores to identify potential major iceberg blocking events over the past 2000 years encompassing warm phases such as the Medieval Warm Period.

- Analysis of samples from the Evens Piedmont Glacier suggest that marine aerosols are derived mainly from frost flower formation on new annual sea ice, raising the possibility that the geochemistry will provide a record of sea ice formation in the Ross Sea.

The ocean objective of ANZICE aims to identify responses of the Southern Ocean and New Zealand to past warm extremes especially during marine isotope stages 1, 5e, 11 and 31. This is being carried out via isotopic geochemical analysis of foraminifers in marine cores focusing on the stable isotopes $\delta^{18}O$ and $\delta^{13}C$ together with the ratio, magnesium/calcium or Mg/Ca. Collectively, these proxies help identify ocean temperatures, salt content, amount of ice formed in polar regions, ventilation of ocean waters, and plankton production. Achievements include:

- Development of the Mg/Ca technique for local conditions via calibration of the technique with modern foraminifers for which ocean temperatures are known and application of the New Zealand-Southern Ocean calibrated Mg/Ca ratio to existing sediment cores.
- Evaluation of existing stable isotope data to determine changes in water masses off eastern New Zealand over recent glacial-interglacial cycles. Results indicate that the basic structure of major water masses entering the SW Pacific did not change significantly during major climatic shifts.
- Published reviews on the modern physical oceanography of the Southern Ocean and its responses to past climate change, as essential background material for ANZICE.
- A detailed recorded of storms and precipitation for the late Holocene has been derived from a 27 m-long sediment core from Lake Tutira, Hawke Bay. The frequency of major storms reveals distinct patterns that appear to reflect both Antarctic forcing via the Southern Annular Mode and equatorial forcing through the El Niño-Southern Oscillation.

The final ANZICE objective deals with the development of analogue and numerical models to provide a means of identifying and projecting changes for the future. Such information will be translated into policy. Again, this objective has progressed well as demonstrated by the following examples:

- Research into the Southern Alps glaciers has concentrated on formulating models that relate regional climatic variables to mass balance (the balance between snow accumulation and snow and ice melt). A regional energy balance model has been developed and applied successfully to assess changes in glacier volume between 1976 to 2006, together with the gradients of mass balance sensitivity from west to east across the mountain range. That model is now being coupled to glacier flow model.
- An intermediate complexity model involving the ice-ocean-atmosphere has advanced significantly, and is presently being coupled to a 'state of the art' three dimensional ice flow model developed at Pennsylvania State University. This will be a powerful tool in investigating change in Antarctica and the Southern Ocean to a warmer world.
- The climate component of the intermediate complexity model has been applied to determine the behaviour of ice shelves to a warmer atmosphere. When tested against past ice shelf collapses, the model successfully reproduced the demise of ice shelves on the Antarctic Peninsula and in the Canadian Arctic, thus providing confidence in its potential to project future change.

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Overall, ANZICE has made tangible advances towards proposed outcomes (see the Publication List). The initial results have identified past warm periods which along with verified models, will provide a window into future environmental effects. Computer-based models are well advanced and ready for verification against modern and past environmental data. The consistent message that is coming the programme's results is that New Zealand -Antarctica region has its own distinct regional "flavour" that is overprinted by global climatic signals. Such regionality cannot be fully captured by global perspectives of the Earth-Ocean-Atmosphere system. Thus, it is essential to tease out local forcing agents and responses to provide a realistic picture of New Zealand in a projected warmer world.

Contributing to the programme's achievements are Brian Anderson, Joel Baker, Peter Barrett, Nancy Bertler, Annette Bolton, Julia Bull, Lionel Carter, Gavin Dunbar, Jeremy Fyke, Andrew Mackintosh, Julene Marr, Tim Naish, Rachael Rhodes and Sean Weaver. Their efforts are greatly appreciated as are those of our collaborators at GNS Science and the University of Maine (ice cores); Stanford University, Virginia Institute Marine Sciences and NIWA (sediment cores); Victoria University (Canada), Pennsylvania State University and University of Wales (computer models).

iii) Ice core climatology – also an ANZICE objective

The ice core facility has now been operational for its first year and accommodated an exciting variety of activities from researchers and students from a number of institutions. The facility not only allowed us to grow the actual FTE of researchers and in particular students within the ice core programme, but also has been very successful in facilitating national and international collaboration. GNS swipe cards for access to the ice core facility have been given to all the current NZ based associated researchers and students (please see list below) symbolising the successful inter-institutional collaboration.

Current associated researchers: Nancy Bertler (VUW/GNS), Gavin Dunbar (VUW), Rob Mackay (VUW), Warren Dickinson (VUW), Katja Riedel (NIWA), Hinrich Schaeffer (NIWA), Peter Franz (NIWA), Julian Thomson (GNS), Uwe Morgenstern (GNS)

The establishment of the ice core processing facility was a crucial milestone to allow for the involvement of students. The world-class facility, the successful programme and its association with other existing, state of the art laboratories, such as the Stable Isotope Laboratory at GNS, the Geochemistry Laboratory at VUW, and the Gas Laboratory at NIWA, allows us to attract top international and national students.

Current associated students: Julia Bull (MSc, anticipated completion in May 2009), Rachael Rhodes (PhD, anticipated completion in 2011), Isabel Schuck (MSc in collaboration with University of Karlsruhe, Germany, anticipated completion in March 2009), Dan Dixon (visiting PhD student with NSF EAPSI Award), Heather Purdie (PhD – main supervisor, Andrew Mackintosh)

New students: Gifford Wong (PhD Scholarship, awarded), Holly Wilton (MSc, committed, scholarship pending), Lana Cohen (PhD Scholarship pending), Bradley Markle (Fullbright Scholar, NSF scholarship pending)

Over the last year, science output of the ice core programme has been productive. A total of eight oral presentations at national conferences and two posters and two oral presentations at international meetings were presented. One manuscript has been submitted and two further manuscripts are in preparation for submission in the next month. In addition, two MSc theses will be completed by May 2009. New data products include 3,500 stable isotope data for each: $\delta^{18}O$ and dD, 1,200 geochemical analyses, 500 dust analyses, 600 m of high resolution density measurements (dexa), and meteorological data from two operational automatic weather stations. A planned drilling season for 2008/09 was cancelled in favour of

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core processing and the preparation of manuscripts. For 2009/10 a significant drilling season is planned with the currently manufactured VUW ice core drill. Negotiations with Antarctica New Zealand are on the way to decide whether a 750 m deep core will be obtained from Roosevelt Island (with Danish and US Collaboration) or a 600 m deep core from Skinner Saddle (with US collaboration).

In collaboration with GNS Science, the ice core programme held its first New Zealand Ice Core Symposium in December 2008. The productive and stimulating meeting was attended by scientists, policy makers, and stakeholders. A total of 14 presentations were given, including 3 from students, and strategic future research directions were discussed. In addition, the ice core programme has maintained an active public outreach programme over the last year, with one TV interview, two radio interviews, two newspaper articles and two well visited websites.

iv) Glaciers and Climate Change in NZ and East Antarctica – also an ANZICE objective

2008 began with a visit to the ARC by Dr Alun Hubbard (University of Wales) from January-March. Alun was funded by Andrew Mackintosh's Marsden FastStart grant 'Temperature or precipitation; what drives Southern Hemisphere glacier fluctuations'. Andrew and Alun worked on an ice model for New Zealand glaciers at the Last Glacial Maximum – and discovered that a substantial cooling of ~7°C is required to drive glaciers to their mapped moraine limits for this period.

In February, Andrew, Alun, Brian Anderson and Heather Purdie (PhD student) presented their most recent work at the annual New Zealand Snow and Ice Research Group, a regional branch meeting of the International Glaciological Society held at Canterbury University's Cass Field Station (Arthur's Pass). In July and August, Andrew travelled to St Petersburg and Oslo and gave the following presentations:

- Mackintosh, A., Domack, E., Leventer, A., Fink, D., White, D., Gore. D., Dunbar, R. East Antarctic Ice Sheet retreat as a response to Meltwater Pulse 1A. *SCAR/IASC IPY Open Science Conference*. St. Petersburg, Russia July 8th – 11th 2008.
- Brian Anderson and Andrew Mackintosh. Gradients of mass balance sensitivity in the Southern Alps. 33rd International Geological Conference (IGC), Oslo, 6th-14th August 2008.

After returning, Andrew and Brian helped to write a 'Regional Climate Modelling' RFP submission to FRST along with collaborators (Dr Brett Mullan, Dr Sam Dean, Dr Jordy Hendrix and Dr Martyn Clarke) at NIWA, and successfully negotiated a 39 month sub-contract. The objective of this work is to improve regional climate predictions in New Zealand and in particular to calculate the contribution of glacier melt and associated runoff to hydropower/irrigation lakes in the South Island. The additional funding allowed Brian Anderson to negotiate a (0.66 FTE) permanent position at the ARC.

In October, Brian and Andrew worked with Dr Uwe Morgenstern at GNS Science on a Southern Alps/Tasman Glacier RFP from FRST, and there is a strong likelihood that we will be subcontracted by GNS Science to carry out numerical modelling and survey work with the aim of identifying high quality ice core sites in New Zealand. In November, in a bid to boost our capacity in ice modelling, we made a 3-year fixed term Post-Doctoral offer to Dr Nick Golledge from the British Geological Survey/University of Edinburgh. Nick accepted and will arrive in March 2009.

v) Permafrost and ancient ice in McMurdo Dry Valleys

This programme, which is partially supported through ANDRILL, is to learn the origin and age of fossil ice found in the McMurdo Dry Valleys. This will help constrain the timing of development of the present ice sheet and enable periods of ice retreat and advance to be reconstructed. The focus this year was analysis and writing.

A paper from Martin Schiller's MSc thesis (2007) has been accepted in the *Journal of Geophysical Research*. This paper describing the distribution of ^{10}Be in volcanic ash from the Wright Valley showed

that the climate of the McMurdo Dry Valleys was warmer and wetter prior to four million years ago, supporting the ANDRILL finding of an ice-free Ross Sea during the Pliocene warm period. A second paper from the thesis work has been written, but it is waiting on radiometric ages from Bill Mackintosh in New Mexico.

A manuscript from Gretchen Williams' Hons project (2006) has now been submitted to *Arctic, Antarctic and Alpine Research*. It uses geochemical fingerprinting to help understand the origin of granite clasts in till on the floor of Beacon Valley, helping constrain the timing and deposition of the Beacon Valley till, which overlies the controversial 8 million year old relict ice.

Much of Warren Dickinson's time in 2008 was spent working in the SGEES ultraclean lab separating and measuring Magnesium stable isotopes from Fe-Mn nodules from the Chatham Rise. The nodules range up to 15 million years old and provide a record of ocean chemistry as they precipitate on the seafloor. Initial results show that the Mg isotopic values track the well documented Strontium isotopic values. By modelling the Mg isotopes, Warren will construct a record of Mg concentration in seawater. This will be used to constrain ancient ocean temperatures obtained from Mg/Ca ratios measured in marine fossils. A record of Mg concentrations also constrains the past rates of sea floor spreading and continental erosion. In early 2009, Warren will submit a paper to *Holocene* on optical luminescence dates (OSL) of sands from the Victoria Valley dunes. This work shows that the sand dunes, which were previously thought to be frozen and immobile, are in fact highly mobile, and constrains the age of the dunes and the climatic parameters that cause the formation of the dunes.

vi) Science Drilling Office

Activity in the Science Drilling Office during 2008 focussed on three major tasks. Firstly, completion of reporting and documentation for the ANDRILL McMurdo Sound Portfolio (MSP). As part of this, Alex Pyne presented a technical report on the MIS and SMS drilling operations to the ANDRILL Operations Management Group (AOMG) in St Petersburg in July. The second major ANDRILL task was the development of drilling and operational strategies for the proposed Coulman High drill site, including input into a NSF proposal, and development of an Operations Scoping Document. The third major task was development of the VUW Ice Core Drilling System, funded through VUW Capex. Alex Pyne has been working with plans from Danish colleagues at the Centre for Ice and Climate at the Niels Bohr Institute (University of Copenhagen) and talking to variety of suppliers and manufacturers around New Zealand and overseas. The Drilling System is planned to be completed in 2009.

Alex Pyne

Alex Pyne was awarded a New Zealand Science and Technology Medal from the Royal Society on 25 November. The award citation recognized Alex's leadership in the field of polar drilling technology, which has enabled recovery of continuous records of past environments in the challenging environment of Antarctica.

In December, SDO recruited a new Operations and Field Engineer. Darcy Mandeno will start with the SDO in March, and will be focused initially on the Ice Core Drill development, but will support all our drilling technology operations in New Zealand and Antarctica.

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6. OTHER SIGNIFICANT EVENTS IN 2008

i) Antarctic Study Tour

In February, forty-six travellers led by Prof Peter Barrett and Dan Zwartz boarded the vessel '*Professor Molchanov'*, for a VUW Centre for Continuing Education & Executive Development study tour to the Antarctic Peninsula. The idea was conceived in 2006 by Peter while planning for the Victoria University Antarctic Expeditions 50th anniversary reunion. They decided that a tailored tour to the Peninsula would be a fitting way to reach out to people who had their eye on the Antarctic and an interest in science and the environment. The participants were well prepared, having had a series of lectures on Antarctic history, science, and law before leaving Wellington. The experience was recorded by journalist, Stephanie Gray, her 'Slice of Ice' blog can be found at http://slice-of-ice.blogspot.com/. Another tour is likely to be run again in 2010.

ii) Peter Barrett Celebration

On the 26th March there was an official opening and unveiling of ARC meeting room – named the Beacon Room in honour of Prof Peter Barrett, the first Director of the Antarctic Research Centre from 1971-2007 in recognition of his work and discovery of the first tetrapod remains in the Beacon Supergroup, a succession of Devonian to Triassic (420-200 million years old) sedimentary strata that stretches the length of the Transantarctic Mountains. The following week, on the 2nd April, there was a celebration to formally mark the stepping-down of Peter as the ARC Director and to highlight his achievements during this time. The Vice-Chancellor, Prof Pat Walsh, opened the ceremony, and speeches were given by Prof Tim Naish, who has taken over the role of ARC Director and Alex Pyne, who told some interesting stories on Peter's earlier adventures in Antarctica.

iii) Annual S.T. Lee Lecture in Antarctic Studies

The 2008 S.T. Lee Lecture "*Through a Crevasse Darkly: An Update on the Future of the Antarctic Ice Sheet*" presented by Richard Alley, Evan Pugh Professor of Geosciences, The Pennylvannia State University, was brought to us via live videolink. Richard has been particularly successful in advancing understanding of the behaviour of ice sheets, glaciers and ice shelves and is very candid about the many unknowns concerning global warming and its effects, earning him respect from those on both sides of the issue. His dynamic presentation highlighted many new discoveries that show that elements of Antarctic ice cover are surprisingly sensitive to warming and could accelerate sea-level rise. Yet, translating these new results into accurate projections for use by policy makers remains a major challenge. Richard's presentation was followed by questions from a panel consisting of Dr Nancy Bertler, Antarctic Research Centre; Prof Jonathan Boston, Institute of Policy Studies; Dr Andrew Mackintosh, School of Geography, Environment and Earth Sciences; and Prof Martin Manning, Climate Change Research Institute. Prof Peter Barrett, Antarctic Research Centre and Climate Change Research Institute chaired the session. The talk can be downloaded from our website at www.victoria.ac.nz/antarctic/about/lee-lecture/lecture2008.aspx.

Richard Alley

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iv) S.T. Lee Student exchange with University of Alaska Fairbanks

Keleigh Jones taking measurements in the field

Keleigh Jones from the School of Chemical and Physical Sciences, was awarded the 2008 S.T. Lee Young Researcher Travel Award. The award gave her the opportunity of travelling to the Barrow Arctic Science Consortium (BASC), Barrow, Alaska (515 km above the Arctic-Circle) in May. At BASC she carried out measurements for her PhD research, looking at producing 3D models of the resistivity structure of sea-ice and participated in an interdisciplinary sea-ice research field techniques course. It involved students and leading sea-ice researchers from all over the world and covered a diverse range of topics from ice optical properties to ring seal monitoring to Iñupiaq sea-ice knowledge.

v) ANDRILL Celebration

Antarctica New Zealand and Victoria University of Wellington hosted a function at Rutherford House on the 27th May to celebrate the scientific and technical achievements of both the ANDRILL McMurdo Ice Shelf (MIS) and Southern McMurdo Sound (SMS) drilling projects. Guest speakers included Hon Pete Hodgson, Minister of Research, Science and Technology; Murray Bain, Chief Executive, Foundation for Research, Science and Technology; and Dr Alex Malahoff, Chief Executive, GNS Science. Presentations were also given to Jim Cowie, Project Manager and Alex Pyne, Drilling Science Manager for their outstanding contributions to the ANDRILL project.

vi) NZ Antarctic Conference

The 2008 Annual Antarctic Conference was held in Dunedin from 30th June to 2nd July. The theme of the conference was 'International Polar Year and the Next Generation' and concentrated on science events that Antarctica New Zealand has supported in recent years, with some presentations from artists and media programme participants. In keeping with the conference theme, the main conference was preceded by a half day workshop for students and early-career polar researchers, entitled 'Career paths in NZ polar research: From student to Principal Investigator'.

vii) Science Careers Expos

Gavin Dunbar and Rob McKay during the VUW Science Careers Expo.

The Antarctic Research Centre participated in both the University of Auckland and Victoria University of Wellington Science Careers Expos held on the 30th July and 14th August, respectively. The Auckland event was a joint Antarctic research display organised by Shulamit Gordon from Antarctica New Zealand. Students were encouraged to look into the various universities and research institutes they may be interested in and contact the researchers directly to show their interest in further study. Gavin Dunbar and Rob McKay fielded enquiries for the VUW event, which directly focused on the courses and research undertaken by the ARC.

viii) Alan Eggers Donation

The Alan Eggers $1M donation was reviewed by Peter Barrett, Tim Naish, Mike Hannah, Dave Bibby, and Paul Callaghan who decided to split the fund, with $250K invested in the ARC Endowed Development Fund, $250K for the establishment of the Science Drilling Office, $300K to fund a 3-year fixed-term Post-Doctoral Fellowship in ice and climate modelling, and $50K to support the New Zealand International Ocean Drilling Program (IODP) subscription. This leaves a further $150K available to increase capability in ice core and climate modelling.

ix) ARC Endowed Development Fund

More than $450,000 has now been committed to the Endowed Development Fund Appeal, including the addition of $250K from the Alan Eggers donation and an additional $50K from Antarctica New Zealand during 2008. This enabled an increase in the number of graduate students who could get support from the fund this year. Recipients included Julia Bull, Rosie Cody, Jeremy Fyke, Rob McKay, and Rachael Rhodes from the ARC, as well as Alison Glenny and Sylvie Haisman, International Institute of Modern Letters, and Eileen Koh, Andrew Martin, and Meghana Rajanahally from the School of Biological Sciences. The funding helped cover costs of attendance at the SCAR Conference (St Petersberg), International Geological Congress (Oslo), International Conference on Polar and Alpine Microbiology (Banff), and Imaging Antarctica Conference (Christchurch), as well as analytical analyses and travel for collaborative work at other institutions including University of Tasmania (Hobart) and Pennsylvania State (USA).

x) Visitors

The ARC had a number of visiting academics during 2008, including:

Dr Alun Hubbard, Aberwrystwth – glacial modeling (hosted by Andrew Mackintosh
Dr Reed Scherer, Northern Illinois – ANDRILL paleontologist (hosted by Tim Naish)
Dr Phil Kyle, New Mexico Tech – ANDRILL volcanologist (hosted by Tim Naish)
Prof Jaap van der Meer, Queen Mary – glaciologist (hosted by Peter Barrett)

7. COLLABORATIONS WITHIN VICTORIA UNIVERSITY

ARC supports a significant proportion of the research being carried out in the palaeoclimatology research theme in the School of Geography, Environment and Earth Sciences. There is also close interaction between ARC staff and projects with other research programmes in geophysics, geology, physical geography, and the environmental studies programme.

Teaching programme

ARC teaching makes a substantial contribution to the geology programme within SGEES in stratigraphy, sedimentology and palaeoclimate at both undergraduate and graduate levels, and also provides the theme for a first year course in SGEES (ESCI 132 – Antarctica: Unfreezing the continent). The course draws on the Antarctic experience of staff and students to introduce science to non-scientists along with the unique history, politics and environmental issues of the last continent. A formula based on the % contribution to each course by ARC staff, and the revenue SGEES gains from Government grants and student fees has been used as a basis for a transfer of funds from SGEES to ARC, and provided approximately $160,000 to the 2008 ARC budget.

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Staff of the Antarctic Research Centre contributed to teaching in the School of Geography, Environment and Earth Sciences in the following courses:

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
ESCI 403	Stratigraphy and Palaeontology
ESCI 404	Special Topics
ESCI 412	Quaternary Geology

The teaching programme also includes supervision of graduate students at MSc and PhD levels.

8. COLLABORATIONS AND NETWORKS OUTSIDE THE UNIVERSITY

i) Joint Antarctic Research Institute (JARI)

The JARI Executive met in January, March, May, June and November. The initial focus on the development of the Ice Core Facility continued (see earlier item) and on the collaboration resulting from the successful ARC ANZICE and GNS Science GCT bids into FRST's Global Change portfolio, with both programmes starting in late 2007. A new focus on glacier modeling and climate led by Andrew Mackintosh, ARC, has also been developed through the year. Later in the year the JARI Board was advised that NIWA had agreed to join. An expression of interest was also received from University of Otago. An internal review by the Director in late 2008 led to a Restatement and Amendment of the original agreement to include NIWA and to reflect the way in which JARI was successfully working. This will be reviewed and confirmed at the JARI Board meeting on March 5 2009.

ii) VUW initiative towards a Climate Change Institute

The New Zealand Climate Change Research Institute (CCRI) was established by Victoria University of Wellington in late 2007 to develop interdisciplinary research into all aspects of climate change. In particular, the CCRI recognises a need to better integrate social and natural sciences, and for independent analyses of policy options for New Zealand. The CCRI Director is Professor Martin Manning, formerly with the Intergovernmental Panel on Climate Change. Prof Peter Barrett was appointed Deputy Director, and Dr Andy Reisinger was appointed as Senior Research Fellow during the year. Dr Reisinger was also formerly with the IPCC. The establishment of the CCRI was also guided by Prof Jonathan Boston (Institute of Policy Studies), and Assoc Prof Ralph Chapman (Environmental Studies).

iii) Other collaborations in New Zealand

In 2008, we continued to build our collaborations and networks outside the University. Antarctica New Zealand continues to be a key partner, particularly in the ANDRILL project, but also in logistics support for ice core climatology. Links with GNS Science and NIWA continue to develop through JARI (see above). We also are currently carrying out joint research within New Zealand with the Universities of Canterbury and Otago on NZ glaciers and their history, and through ANDRILL.

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iv) Other international collaborations

Collaboration continues in various ways with the Universities of Leeds, Maine, Aberystwyth, Edinburgh, London (QMC), Alaska, Chicago, Washington, Texas at Austin, as well as Lamont, McGill, Northern Illinois, University of Massachussetts, Harvard, Cambridge, University of Nebraska-Lincoln, Stanford and the Ohio State Universities. We also collaborate closely with the Alfred Wegener Institute, Bremerhaven, for glaciology and ice shelf work.

A new international initiative this year is our partnership in a consortium for New Zealand membership of the Integrated Ocean Drilling Program led by GNS Science. We are particularly interested on account of the upcoming drilling leg off Wilkes Land, Antarctica which begins and ends in Wellington (January 4 to March 12, 2010). Rob McKay will sail as a sedimentologist.

9. OUTREACH

Staff, students and visitors at the ARC were involved in a variety of outreach activities during the year. These included talks to community groups, interviews (newspapers, radio and television), and school visits. These present our research and knowledge to the wider community both here and overseas. A few examples indicate the breadth of activity:

- Minister Hon. Pete Hodgson Tour of ARC: Tim Naish
- German Delegation Tour of ARC: Tim Naish
- International Polar Year Day, Online-talk: Tim Naish and Tamsin Falconer.
- Careers Advisors Tour: Tamsin Falconer.
- Amicus Meeting, Tauranga: Tim Naish.
- University of Texas MD Anderson Children's Cancer Hospital, Houston "*Polar Blast*": Lionel Carter, Nancy Bertler, and Michelle Dow (via video-link).
- 5th Quaternary Techniques Short Course, GNS Science: Lionel Carter.
- "*Café Scientifique*" public talk: Gavin Dunbar.
- Progetto Smilla Teachers Workshop, Parma,Italy: Tamsin Falconer.
- NZ Science Teachers Conference 2008: Gavin Dunbar and Michelle Dow.
- Tertiary Education Commission *"Today and Tomorrow"*: Tim Naish, Michelle Dow, and Tamsin Falconer.
- Wairarapa Geological Society, Masterton: Peter Barrett.
- Kaleidoscope Kapiti U3A: Lionel Carter.
- 7th Annual Kids Conference 2008: Warren Dickinson, Tamsin Falconer, and Julia Bull.
- Wellington Astronomical Society, Talk by Tim Naish
- Crown Prince of Perak State, HRH Raja Dr Nazrin Shah Tour of ARC: Peter Barrett and Tamsin Falconer.
- Ice Floe production of "*Heat"*: Tamsin Falconer.
- Weir House 75th Anniversary Tour: Peter Barrett and Tamsin Falconer.
- Wellington College (Year 9-History): Tamsin Falconer.
- The Dominion Post (5): Tim Naish, Peter Barrett, Andrew Mackintosh. (front page Naish on Wilkins ice shelf collapse).
- Grey Star: Brian Anderson
- Bay of Plenty Times: Tim Naish.
- Capital Times: Nancy Bertler.
- Radio New Zealand National: Tim Naish, Peter Barrett, Lionel Carter, Nancy Bertler, Tamsin Falconer and Rachael Rhodes. (Our Changing World, Nine-till-Noon, Morning report, Frontline, News)
- Prime News*:* Nancy Bertler.

"Polar Blast", 27 June 2008

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In addition, the ARC Newsletter IceSked is sent out to over 400 alumni, associates and institutions. Nº 10 was issued in June 2008 celebrating the achievements of Prof Peter Barrett, as he stepped down as Director of the ARC in January. It also highlighted the ANDRILL Southern McMurdo Sound project and other projects on the ice. The following issue in December, focussed on the research undertaken by some of the staff and students within the ARC and reflected on the current status and recent recipients of our Endowed Development Fund.

Feature film on Antarctica and Climate Change

The joint project between VUW, Oxford University and London-based DOX Productions has now completed its second year with several significant achievements. To date, filming has included 40 hrs of material from Antarctica during the 2007/2008 field season, a nine day oceanographic research cruise in the Southern Ocean, and filming the negotiation process on climate change issues at the United Nations Framework Convention on Climate Change meeting in Bonn, Germany. Filming of climate modeling in the UK and carbon capture and storage projects in Europe in late 2008 completed almost all of the planned filming. Post-production will take place in early to mid 2009 with cinema release by the end of the year. Both universities are financially supporting the project.

10. FINANCIAL POSITION

The ARC budgets for 2008 and 2009 are summarized in the table below.

INCOME[1] **(000)**	**Budget 2008**	**Actual 2008**	**Budget 2009**
	$968	**$840**	**$862**
Research revenue[2,4]	$544	$413	$440
PBRF	$254	$262	$269
SGEES teaching	$161	$161	$149
S Lamb grant[3]	$4	$4	$4
Donations[4]	$5	$0	

EXPENDITURE[1] **(000)**	**Budget 2008**	**Actual 2008**	**Budget 2009**
	$1009	**$819**	**$901**
People[4,5]			
Salaries & associated	$812	$585	$637
Other			
Equip & furniture	$5	$4	$2
IT	$16	$19	$18
Operating[4]	$38	$79	$85
Depreciation	$26	$26	$44
Storage	$17	$17	$21
Occupancy (space)	$95	$88	$94
SURPLUS/DEFICIT[6]	**-$41**	**+$21***	**-$39**

NOTES:

[1] All figures are exclusive of GST.

[2] Research revenue shown is net to the Antarctic Research Centre (salaries and overhead). Direct costs for research work are managed in accounts held through the Research Trust of Victoria University of Wellington.

[3] A transfer from the Simon Lamb DVCR Sponsorship grant to cover the cost of the depreciation of the camera equipment purchased in 2006.

[4] Donations included money from the Alan Eggers fund targeted to underwrite costs of the Science Drilling Office (SDO). However the SDO budget was transferred to a Research Trust grant in October so all income and expenditure was removed from Cost Centre actual budget. This is reflected in lower Research revenue, lower salaries and $52.2K transfer under Operating to support the SDO.

[5] Includes a transfer from the Climate Change Research Institute to cover their share (0.3FTE) of Peter Barrett's salary costs.

[6] Budgeted deficit figures of $41K and $39K represent allowable targets imposed by VUW.

* Profit for 2008 primarily due to increased PBRF funding, reduction in annual leave balances, and some occupancy charges not debited.

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Income is derived from the following sources:

1) *Research Revenue:*
    a. FRST
        - ANDRILL science. VUW part of major grant to GNS, U Otago and VUW, which runs through to 2010
        - ANZICE project started October 2007 and runs through to mid-2011, supporting work of glacial modeling, sediment from oceans and ice core research on glacial-interglacial climate extremes.
        - Bertler 'Bridge to Employment' funding as a continuation of Nancy Bertler's Post Doctoral Fellowship from July 2007 to June 2008.
        - New Regional Modelling NIWA sub-contract started October 2008 until December 2011.
    b. Marsden
        - Funding to support Peter Barrett and Gavin Dunbar as part of a major Marsden grant to Tim Naish (GNS) through to December 2008.
        - Bertler FastStart supports collaboration with NIWA and small part of salary for Nancy Bertler and Tim Naish through to June 2009.
        - Marsden FastStart to Gavin Dunbar starting in April 2008 through to March 2010.
        - Mackintosh FastStart for Southern Hemisphere glacier work closes in February 2009.
        - Small amount of work on Townend Marsden by Lionel Carter from April 2008.
    c. Antarctica NZ
        - Income on contracts based on an hourly rate charge for work in NZ, and a day rate for Antarctica, for both Alex Pyne and Tamsin Falconer for the ANDRILL and Coulman High contracts which ran through to June 2008.
    d. Other
        - contract with International Cables Protection Committee to Lionel Carter.
        - Lake E Test Drill to Alex Pyne.
2) *PBRF*: The amount transferred to ARC is calculated by VUW based on external research funding that meets the PBRF criteria, plus the quality rating of staff in the ARC. At present, ARC does not get funding for research degree completions, which are recorded under SGEES.
3) *SGEES teaching*: $160,694 was transferred to ARC from the School of Geography, Environment and Earth Sciences for teaching services by ARC staff in 2008.

Successful funding proposals in 2008:

1. $70K NIWA sub-contract (funded through FRST) to Andrew Mackintosh and Brian Anderson for regional glacial modelling work.
2. $110K Internal VUW major CapEx, approved to purchase a Ground Penetrating Radar (GPR) unit.
3. $38K Internal VUW minor CapEx approved to purchase videoconferencing technology for the Beacon Meeting Room.
4. $50K Internal grant to Simon Lamb for continuing support of his work on the climate change film.
5. $9K Faculty Research Grant awarded to Gavin Dunbar for reconstructing climate seasonality from molluscs.

11. PLANS FOR 2009 AND BEYOND

i) Research programmes

In the last couple of years ARC has developed significant new capability through past experience and new resources to lead research in four fields, all related to past and present climate in the Antarctic-New Zealand region:

i) Antarctic sediment coring (carried out under the ANDRILL project banner)
ii) Antarctic-NZ ocean history
iii) Antarctic ice core climatology, and
iv) Ice and climate modeling (the last three carried out under the ANZICE project banner, but also with other significant linkages)

This section includes some brief notes on each.

ANDRILL in 2009 will consolidate its body of scientific results and continue to publish in international journals. FRST ANDRILL programme funding is scheduled to reduce to ~$600K in July 2009. We are currently negotiating a 2-year continuance at the present level of funding. This will enable ANDRILL results to be adequately synthesized and published and allow time for a future Antarctic paleoclimate programme to be negotiated with FRST, Antarctica NZ and its providers. A "white paper" has been requested by FRST following the Review, outlining this programme, and is being prepared by Tim Naish, Richard Levy and Gary Wilson and will be submitted in early April 2009. ARC continues to help develop international funding proposals with our ANDRILL and IODP partners for future Antarctic drilling both from a scientific and operational perspective (eg. Coulman High NSF and EuroANDRILL proposals and an IODP proposal to drill eastern Ross Sea Neogene records of the WAIS.

Two Marsden proposals were submitted in 2009. One is a full proposal to support Rob McKay's involvement in the IODP Wilkes Margin Expedition. It also supports shore-based science by Tim Naish, Lionel Carter, Joel Baker and international collaborators. This proposal made it to the 2nd round in 2008. The other proposal is a fast-start led by Cliff Atkins and involving Gavin Dunbar to study the role of Iron-rich wind-blown dust on phytoplankton productivity in McMurdo Sound.

New Zealand has joined IODP as part of an Australasian consortium (ANZIC) and NZ scientists have been manifested for ship-board positions on the Antarctic Wilkes Land (January 04-March 12, 2010 leg, departing from and returning to Wellington). The objective is a drilling transect to recover climate history from the Wilkes margin for the same period as the Cape Roberts and ANDRILL cores and possibly beyond (last 40 million years).

ANZICE has a range of staff and student projects underway. Pioneering work is being carried out on Mg-Ca paleothermometry based on microanalytical techniques in the new SGEES geochemistry laboratory. Microfossils in cores from the modern sea floor between the tropics and the Ross Sea are providing the "ground truth", and work is underway for extracting them from cores for analyses to estimate sea surface temperatures from past warm periods in the last million years or so.

This year the ice core programme will focus on analytical work in the new ice core facility on cores and samples already recovered, with results expected from Cape Hallett and Mt Erebus cores, though in the latter case gas analysis work may run into early 2010 as the new sampling system is tested and checked. We expect to see the construction of the new drilling system completed. Through discussions with Antarctica NZ it looks like a field campaign to recover a 1000 m-long core from Roosevelt Island is planned for the 2009-2010 summer. This will require a drill system to be available. At this stage we are anticipating components of both the ARC and Danish drills being used.

Ice and climate modeling work will be further strengthened this year with the appointment of Nick Golledge (formally British Geological Survey/ University of Edinburgh). Nick is undertaking an Eggers-funded, 3-year Post-doctoral Research Fellowship with expertise in glacier modeling. We anticipate starting a new modeling project focused on the dynamics of Transantarctic outlet glaciers feeding the Ross Ice Shelf and WAIS. This higher resolution modeling will be integrated with continental-scale ice sheet models from of collaborators (Robert DeConto, UMass and David Pollard, Penn State). We hope to have both Dave and Rob visit us for an extended period to work with the ARC team. This group will contribute to the NIWA closed-tender FRST contract on regional modelling of future New Zealand climate.

ii) Infrastructure and collaborations

Within ARC the most significant change has been the development of the Science Drilling Office (SDO). The SDO, which sits within the structure of the ARC, has as its main objectives: (1) to ensure that key resources and capability remain in NZ, and (2) to increase the profile of this NZ capability through more effective marketing. A key challenge for 2009 will be the construction of the new ice drill. SDO have appointed a new engineer to work with Alex Pyne. Darcy Mandeno will start with SDO in March and will work on the ice drill. SDO continue contracted preparatory work for the next phase of ANDRILL (the Coulman High portfolio). We expect to be heavily involved in the first stage of Coulman High in 2009,

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which will involve the development of a detailed project plan and budget and preliminary drill system development tasks as well as preparing for environmental surveys. Funding to support this work is currently being negotiated with Antarctica NZ, FRST, NSF and European agencies. ANDRILL has raised the profile of ARC expertise in this field and the new branding should help profile it further. Both ARC and SDO will continue to work with VUW marketing on branding.

ARC staff will continue to work closely with SGEES with whom it shares graduate students and on whom it depends for laboratory facilities. A new agreement is now in place which acknowledges the teaching and supervision of students by ARC staff in SGEES and appropriate sharing of PBRF revenue. The ARC Director is a member of the SGEES Executive and Research Committee and ARC teaching staff will continue to be active participants at meetings of the Earth Sciences Board of Studies.

The formation of the Climate Change Research Institute (CCRI) in the School of Government last year is of interest to ARC on account of its climate-oriented research focus and networks, and the CCRI mission to develop policy options on climate change issues from a sound scientific base. Projects that have developed from within ARC, such as the Climate Change film and the Antarctic Peninsula Study Tour, and the recent Greenhouse Climate Symposium, are examples of outreach that are aligned with both organisations. However the quality and relevance of ARC research to climate issues is also seen as important in supporting the work of the CCRI. Martin Manning has been appointed Professor of Climate Change from January 2008, a significant step forward in the development of the new Institute. Peter Barrett holds a fractional appointment (0.3 FTE) as Deputy Director, and will retain 0.5 FTE with ARC in 2009.

The Joint Antarctic Research Institute (JARI) will continue to consolidate in its role as a research alliance between GNS Science, VUW and NIWA. Peter Barrett who worked tirelessly as Director in 2008 has co-ordinated a new joint agreement that simplifies the scope and function of the JARI emphasising its role in aligning effectively research of mutual interest. The new agreement with its revised Executive Management Structure will be presented to the JARI Board on the 5th of March for approval. The JARI will continue to look at involving other external collaborators (such as Otago and Canterbury universities) in its activities and meetings with a view to eventually expanding the membership. Alex Malahoff will chair the JARI board in 2009 and new officers of the Executive Committee and Board will be filled.

Internationally, our research lies within the domain of two of the five SCAR Research Programmes, Antarctic Climate Evolution (ACE) and Antarctic and the Global Climate System (AGCS). ACE is led by Robert DeConto (Massachussetts) and Carlota Escutia (Grenada) – Andrew Mackintosh sits on the executive committee and Tim Naish and Peter Barrett have advisory roles. ACE has produced four special issues of articles on Antarctic paleoclimate in international journals, and published a book by Elsevier with chapters by Peter Barrett, Lionel Carter and Tim Naish. An ACE meeting was held in Edinburgh in April, 2008, where plans for the next 4 years were discussed. ACE will host a major Antarctic Climate Meeting in Grenada, Spain in 2009. AGCS is led by John Turner (BAS) and Nancy Bertler is on the committee. AGCS now has in press in Reviews of Geophysics a paper on the state of the Antarctic climate system that summarises the many changes attributed to rising CO_2 emissions that are already taking place.

iii) Strategic Planning

In 2009 ARC will undertake a strategic planning exercise involving a facilitated retreat in February to form the basis of a strategic plan. This will align with the Universities strategic plan but will primarily focus on where we want to be in 5 years time, the forthcoming opportunities and challenges and the resources required to get their.

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12. PUBLICATIONS & CONFERENCES

Reviewed publications (25)

Alan, A.S.R., Baker, J.A., **Carter, L.**, Wysoczanski, R.J., in press. Reconstructing the Quaternary evolution of the world's most active silicic volcanic system: Insights from a ~1.65 Myr deep ocean tephra record sourced from Taupo Volcanic Zone, New Zealand. *Quaternary Science Reviews*

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Books/Book Chapters (7)

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Watson,M.I., Yelf, R.J., **Bertler, N.A.N.**, 2008. Bedrock Topography and Isochrone Mapping of five glaciers in Victoria Land, Antarctica. *Proceedings of the 12th International Conference on Ground Penetrating Radar*. Birmingham, UK, 16-19 June, 2008.

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Awards

1) **Annette Bolton** (PhD student) - Student Poster award at the Paleoclimatology summer school in Urbino, Italy, July.

2) **Tim Naish** - 2008 James Lee Wilson Award for Excellence in Sedimentary Geology by the SEPM (Society of Sedimentary Geology).

3) **Rachael Rhodes** (PhD student) – Winner of student oral presentations at the GeoSciences 08 Conference, Wellington, November.

4) **Alex Pyne** - awarded one of four 2008 Royal Society New Zealand Science and Technology Medal for his leadership in the field of polar drilling technology.

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