VICTORIA UNIVERSITY OF WELLINGTON
TE HERENGA WAKA

Te Puna Pātiotio Antarctic Research Centre

Annual Review 2020

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

Skelton Glacier, Antarctica - Photo: Shaun Eaves

IMPROVING UNDERSTANDING OF ANTARCTIC CLIMATE AND ICE SHEET PROCESSES, AND THEIR IMPACT ON NEW ZEALAND AND THE EARTH SYSTEM

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Antarctic Research Centre Annual Review 2020
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Cover Image: Peter Barrett, Skelton Neve, Antarctica, 1970/71 - Photo: John McPherson

2019
Prime Minister's Science Prize
awarded to the "Melting Ice and Rising Seas" team led by the ARC.

65 year legacy
of Emeritus Professor Peter Barrett celebrated during a two day symposium.

1
New Zealander
Ruzica Dadic, joins the world's largest international polar research expedition, MOSAiC.

10
times
more likely to get extreme glacier melt with human-induced climate change.

8
modellers
from three institutes working together to provide future projections on Earth's climate system.

200
people
attended the 17th S.T. Lee Lecture in person and online.

$6.3
million
in revenue obtained by ARC in 2020, 75% from externally funded grants.

$800
thousand
added to the ARC Endowed Development Fund from the PM Science Prize award and other donations.

$18
thousand USD
awarded to Rob McKay for the Asahiko Taira Scientific Ocean Drilling Research Prize.

1000
metres
of drill pipe ordered for sub-ice shelf drilling for the next Antarctic field season.

2
promotions
in 2020. Introducing: Associate Professor Huw Horgan and Professor Nicholas Golledge.

17
November
the Antarctic Science Platform National Modelling Hub was formally opened by Hon David Parker.

2
scholarships
from Antarctica New Zealand awarded to ARC supervised students, Matthew Tankersley and Theo Calkin.

7
PhD theses
submitted in 2020 by ARC supervised students.

51
publications
in 2020 with ARC staff and student authorship.

5 *Nature* & *PNAS*
publications by ARC staff in 2020.

60
interviews
given by ARC staff and students on Antarctic and climate related issues.

27
presentations
given to politicians, stakeholders, schools and community groups by ARC staff and students.

TE PUNA PĀTIOTIO — ANTARCTIC RESEARCH CENTRE IS A CENTRE OF RESEARCH EXCELLENCE AT TE HERENGA WAKA — VICTORIA UNIVERSITY OF WELLINGTON

DIRECTOR'S SUMMARY

Associate Professor Rob McKay
Director, Antarctic Research Centre

The major headline from 2020 is of course COVID-19, and the challenges this has placed on all aspects of our lives. It is difficult to believe that this time last year, we were only just starting to realise the potential consequences of this new emergent virus. As countries started the processes of border closures and lockdowns, it was quickly apparent that our team at Te Puna Pātiotio — Antarctic Research Centre would have to quickly adapt to meet this challenge. Our team responded exceptionally to the changes in our work environment over the course of the entire year. Curiously, one thing we all recognised during the Level 4 lockdown was that polar researchers have unique qualities that were well suited to some of these challenges, including working in an isolated bubble of a few people for numerous weeks, daily shifts in unforeseen work tasks; and having uncertainties over when this would all finish. These were all scenarios we experience during most Antarctic field seasons, and although it was still a challenge for us, the resilience of our researchers to adapt to this new way of working was remarkable. Looking through 2020 and beyond, COVID-19 has reminded us of the importance of our long-term strategy of developing and maintaining a diverse, resilient and adaptable research programme.

The cancellation of the 2020/21 field season although disappointing was clearly warranted. We were well prepared for this possibility from the beginning of the year, and appreciated this quick decision by Antarctica New Zealand that allowed us to focus on adapting our workflows. While it is safe to say that planning for a global pandemic was low on our list of risk planning prior to 2020, we work every year to the assumption that numerous external drivers could result in such an event. In many ways, having half a year to prepare for the loss of a season is less of a shock than previous events we have seen - such as the early break out of sea ice that terminated the first season of Cape Roberts Project in 1997, only a few weeks into the project. These sorts of issues are part of the deal with working in Antarctica, and consequently we had a contingency year for a lost field season built into our planning for our major Antarctic Science Platform commitments. However, the season as a whole was not lost to us due to the outstanding support from Antarctica New Zealand who were successful in conducting a traverse across the Ross Ice Shelf, leaving crucial supplies and equipment for the Hot Water Drill (HWD) and Antarctic Intermediate Depth Drill (AIDD) systems. This is a major outcome that is critical to the success for our upcoming drilling seasons, and greatly reduces the risk of another lost season down the line. Antarctica New Zealand were also successful in collecting critical oceanographic and glaciological datasets, and we are hugely thankful for their efforts.

If a field season had been scheduled, it would have placed extreme pressures on our building of the AIDD, due to the COVID-related slowdown in the global supply chain of drilling equipment and consumables. The delayed field season provided our Science Drilling Office several extra months to overcome these challenges, and work on getting this build completed in 2021. On this front, our engineers Darcy and Alex are well on schedule, with the drill rig arriving in Wellington and currently undergoing testing and integration with the HWD system.

The loss of the Antarctic field season in 2020/21, and the potential that some of our smaller projects could face some hurdles in upcoming seasons if the logistical bottle neck created by COVID-19 flows through to future seasons, highlights the importance of the diversification of our research portfolio. Even without Antarctic field work, we have maintained exceptional momentum through this difficult time period, with a record number of research papers published, alongside a record number of active external research contracts and staff numbers. The success in New Zealand's elimination strategy with short, sharp lockdowns has allowed our research laboratories to stay open, and our researchers to interact in person, and to attend and host national conferences. The shift in much of our research focus towards computer-based work and data science over the last decade has paid real dividends in this current scenario, with the opening of the Antarctic Science Platform National Modelling Hub in 2020 being a major milestone in the evolution of our Centre. For other Antarctic-related programmes, we have a backlog of legacy material that has been sampled in previous decades, and although not a replacement for carefully planned new sampling campaigns, a year off from field work has forced us to think creatively about maximising the usage of these important legacy resources.

Similarly, we have several New Zealand based research programmes that highlight just how diverse our research portfolio has become, and the importance of our collaborative partnerships with GNS Science and NIWA. Working with these partners, the NZ SeaRise programme continues to provide guidance on adaption and resilience to future sea-level rise resulting from ice sheet loss, while our glaciology teams continue to monitor glacier loss in the Southern Alps.

Remarkably, we did manage to get one researcher to the polar regions during the year. Ruzica Dadic was scheduled to travel to the Arctic in early April, where she was to stay on the German icebreaker *RV Polarstern* as part of the MOSAiC project, the world's largest polar expedition ever. This expedition sought to understand sea ice processes over an entire year, during which the icebreaker was frozen into the sea ice. Her initial scheduled two month shift on this expedition coincided directly with border closures, and was delayed several months. This allowed Ruzica and the MOSAiC team time to develop rigorous quarantine and travel procedures, although this extended her trip duration to almost four months. Ruzica's involvement in this programme is an outstanding opportunity for her, but also helps place the ARC as a key player in this world-leading sea ice research programme.

In some ways, it could be viewed our resilience to COVID-19 has been a function of fortunate timing. While the timing certainly could have been even more disruptive than it was, this resilience is really down to the sustainable growth we have experienced over the past decade. This growth has allowed us to develop a highly diversified research portfolio with a talented team of scientists and support staff, and this greatly spread the risks relating to one-off, or even multiple, unforeseen events.

There was one other headline that in any normal year would dominate this yearly summary column, and that was the awarding of the Prime Minister's Science Prize to the "Melting Ice and Rising Seas Team". This is an outstanding recognition of this team that was led by the ARC, in collaboration with other VUW researchers and our partners at GNS Science and NIWA. This award further emphasises the importance of our diverse research portfolio, that has allowed us to achieve an incredibly high level of impact and relevance, not only to New Zealand but also the global community. Despite the circumstances, it was an incredibly successful year for us, but like everyone we are certainly looking forward to a more normal world in 2021!

RESEARCH OUTCOMES

Pancake ice, Arctic Ocean - Photo: Mario Hoppmann

OUR RESEARCH PROVIDES EXCITING OPPORTUNITIES, A SOUND BASIS FOR INTERNATIONAL CLIMATE CHANGE ASSESSMENT, AND WILL HELP BUILD A MORE RESILIENT NEW ZEALAND

OUR RESEARCH APPROACH

Rationale

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

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

Outcome-based research

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

In summary, our approach involves:

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

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

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

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

e. We disseminate our research findings through publications in the world’s leading scientific journals, and through education, communication and engagement with the public, practitioners and policy makers.

Ruzica Dadic taking snow surface measurements, Arctic - Photo: Mario Hoppmann

ARC PART OF LARGEST POLAR EXPEDITION EVER

Ruzica Dadic was the only New Zealand researcher to join the €140 million MOSAiC project, the largest polar expedition in history.

The MOSAiC expedition involved experts from 20 countries, from more than 70 scientific institutions, who spent a combined year in the Arctic, on the research vessel *RV Polarstern*. With the Arctic regarded as the epicentre for global warming, the expedition aimed to gain insights on the impact of climate change on the Arctic. Arctic sea ice is currently declining at a rate of ~13 percent per decade, relative to the 1981 to 2010 average. We do not yet fully understand the consequences these changes may have for the Arctic climate, and subsequently for the Earth's energy balance. Therefore, an expedition like MOSAiC, where scientists from different disciplines get together to study all the relevant processes and their interactions, will allow us to reduce climate projection uncertainties and create a paradigm shift in our understanding of sea ice.

In September 2019, the *Polarstern* was frozen into the ice to act as a research base for one year. Ruzica was supposed to join the expedition in early April 2020, but COVID-19 altered the plans. Thanks to the huge effort and enthusiastic support of many people, the expedition was not cancelled and Ruzica negotiated boarder quarantines to join the expedition in July 2020, for the last leg of MOSAiC. By July, the *Polarstern* had drifted far south and broken free of the sea ice. So the scientists of Leg 5 sailed back north and found a new floe of sea ice to observe the last piece of the puzzle, the ice freeze-up processes.

Ruzica and colleagues are interested in how snow affects the Arctic sea ice system. Specifically, how the physical properties of snow affect the amount of heat and light that goes into the ocean instead of being reflected back into the atmosphere. Heat contributes to ice melt and determines whether the ocean warms or freezes, while light affects the ecosystem in the ocean below the sea ice. Furthermore, knowledge of physical snow properties is relevant for satellite estimates of sea ice extent, concentration and volume. The team measured physical snow properties using novel, state-of-the art tools across scales ranging from micrometres to 100's of metres. One of the most exciting techniques was micro computer tomography (micro-CT), which allowed the team to measure the microstructure of snow of quasi in-situ samples, which has never been done for snow on sea ice before. We now have a full annual cycle of microstructural information of snow on Arctic sea ice, and the results will reduce current biases in sea ice models and reveal the controlling processes necessary to improve predictive modelling of Earth's energy budget in the context of climate change.

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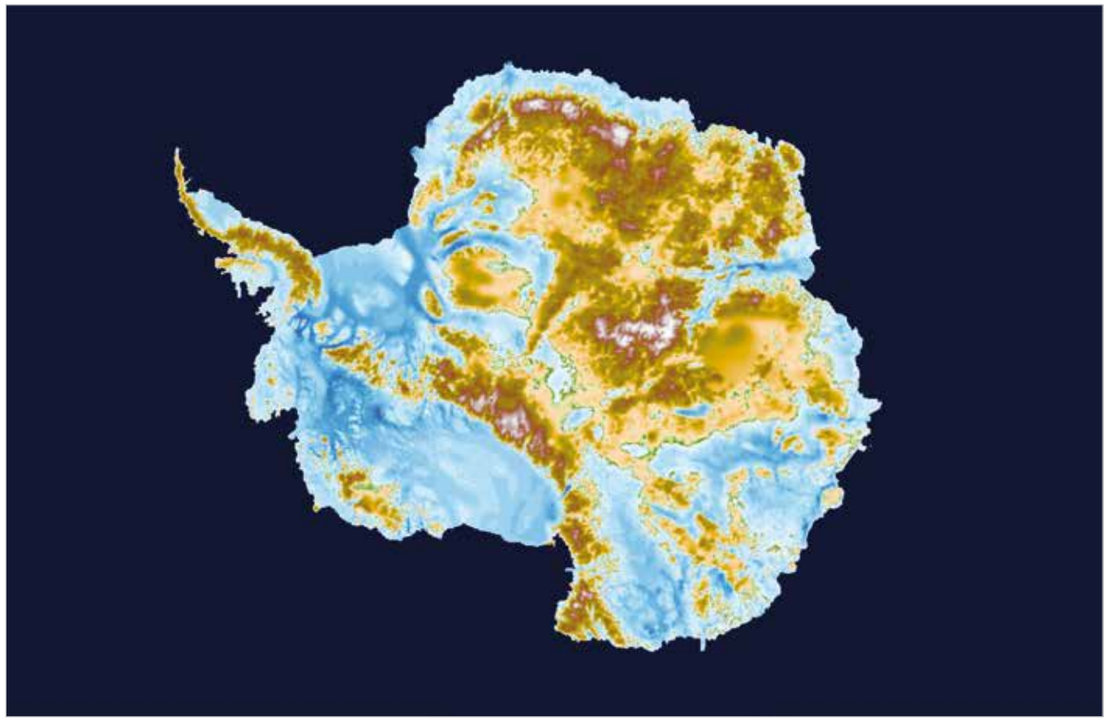

The DeepBedMap Digital Elevation Model of the bed beneath Antarctica's ice sheets and ice shelves. Blue colours indicate elevations below sea level - Image: Wei Ji Leong and Huw Horgan

SUPER-RESOLVING THE BED BENEATH ANTARCTICA'S ICE SHEETS

Mostly hidden beneath kilometres of ice, the base (bed) of the Antarctic ice sheet is perhaps the least accessible landscape on our planet.

At the same time, the elevation and nature of the bed are important constraints to understand how ice slides and flows, and how this movement might change in the future. Most of our knowledge of the bed comes from airborne radio echo sounding, whereby electromagnetic waves are transmitted down through the ice. This energy bounces off the bed, and returns to the plane, at which point the timing of the return is used to estimate ice thickness. Decades of radio echo sounding data, combined with seismic observations beneath the floating ice shelves, has led to gridded compilations of bed elevation, with the most recent generations BEDMAP2 (1 kilometre resolution, Fretwell *et al*., 2013) and the ice-flow consistent Bed Machine (500 metres resolution, Morlighem *et al*., 2020).

To improve on existing estimates of the elevation of the bed, ARC doctoral student Wei Ji Leong has applied a novel machine-learning approach. In a recently published paper in *Cryosphere* by Wei Ji and his supervisor Huw Horgan, a 250 metre resolution upsampled version of the bed is generated by starting with a low resolution (1 kilometre) bed model, alongside several high-resolution patches of the bed. By including other remotely-sensed surface observations such as flow velocity and accumulation, the model is trained and predicts what a high-resolution bed likely looks like elsewhere beneath the ice. The resulting bed estimate (DeepBedMap_DEM) better reproduces properties like the roughness of the bed, which exerts a strong control on the sliding of the overriding ice. Wei Ji's work has opened up a new frontier whereby we can leverage high resolution data, that is logistically feasible to acquire over small areas, and learn about the entire continent.

Fretwell, P., Pritchard, H.D., Vaughan, D.G., Bamber, J.L., *et al.* (2013). Bedmap2: Improved ice bed, surface and thickness datasets for Antarctica. *Cryosphere* 7: 375–393. https://doi.org/10.5194/tc-7-375-2013

Morlighem, M., Rignot, E., Binder, T., *et al*. (2020). Deep glacial troughs and stabilizing ridges unveiled beneath the margins of the Antarctic ice sheet. *Nature Geoscience* 13: 132–137. https://doi.org/10.1038/s41561-019-0510-8

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Adélie penguins, Antarctica - Image: Nick Golledge

ANTARCTIC ICE SHEETS – WAIS-TING AWAY?

The world has been warmer than today, and sea levels have been higher. But surprisingly, our understanding of how quickly a warming climate leads to rising seas is still less than perfect.

That uncertainty is a problem for decision-makers and the general public alike. There are some parts of the so-called 'sea level budget' that are easy to compute – for example, there are well-understood thermodynamic principles that tell us the amount the ocean will expand as it gets warmer. We can get good estimates of how much the global population of mountain glaciers will contribute to sea-level rise if the climate gets warmer, because these bodies of ice are relatively small, are well-studied, and have a direct relationship to rising air temperatures. The major ice sheets of Greenland and Antarctica, however, are much larger and more complex than mountain glaciers, and their changes are very much harder to predict than the thermal expansion of seawater.

To understand how quickly these immense ice sheets – collectively locking up about 65 metres of sea-level-equivalent fresh water – will change as we head into a warmer future we often look to warmer periods of the past for comparison. The most recent time when global climate was warmer than today is the Last Interglaciation, around 130,000 years ago. Somewhat worryingly, global mean sea level at this time was 5 to 10 metres higher than today, even though the climate was only a degree or so warmer. It was warmer then because of changes in Earth's orbital pathway that exposed the Earth to more solar radiation, not because atmospheric CO_2 was higher (in fact it was significantly lower than present values). But nonetheless, we can learn a lot about the effects of future warming by studying how the big ice sheets responded 130,000 years ago. Unfortunately, direct evidence of ice sheet thinning or retreat (which must have occurred in order to produce the higher sea levels) is extremely hard to find, because expansion of the ice sheets during the last glacial cycle, reaching much greater extents than present around 20,000 years ago, has tended to erode away any geological evidence.

This is why sites that record evidence of this past warm period are extremely valuable. One such site exists in the Patriot Hills, West Antarctica, and has been studied by a team from the University of New South Wales (led by Chris Turney) and the University of Keele (led by Chris Fogwill). By sampling and analysing gas from bubbles trapped in the ice, the team found direct evidence that the normal accumulation and flow of the glacier was abruptly interrupted at exactly 130,000 years ago – just when the warming reached it's maximum. The data from the ice core showed that it then took another 50,000 years for normal flow to resume, suggesting that the impact of the warming was substantial. To help define what that impact was, Nick Golledge and others ran computer simulations of the ice sheet under different climatic conditions and compared them with the data. What we found was that abrupt warming of the ocean could lead to ice loss from West Antarctica that could have raised global sea level by up to 4 metres within about 1000 years.

That modelling used simplified climate conditions, so really it just told us about the potential sensitivity of the ice sheet. In another study, published from work Nick undertook with Peter Clark (Oregon State University), and Feng He (University of Wisconsin Madison), a much more sophisticated approach was taken. First, we used a full-complexity general circulation model to simulate the evolving global climate of the Last Interglaciation. Then we used those climate fields as inputs to ice sheet simulations. Despite the very different approach compared to the Patriot Hills study, the Clark *et al.,* simulations again showed that West Antarctica could lose many metres of sea-level-equivalent ice even under very low climate warming scenarios. We found that this sensitivity was directly related to changes in global ocean circulation, combined with self-reinforcing feedbacks in the Antarctic ice sheet.

Together, these two papers showed from field evidence and computer models that parts of the Antarctic ice sheet are very sensitive to only a degree or two of climate warming. These findings are entirely consistent with other studies, but the challenge still remains that the processes controlling the rate at which the ice sheets retreat are still uncertain because we can't observe them directly. The only way to reduce this uncertainty is to gather more observational data and use models to explore a wider range of possible types of ice sheet behaviour to see which fit best with the evidence. As we continue with this work we're beginning to rely more on statistical techniques to help with this, as well as the powerful insights that tools such as machine learning can deliver.

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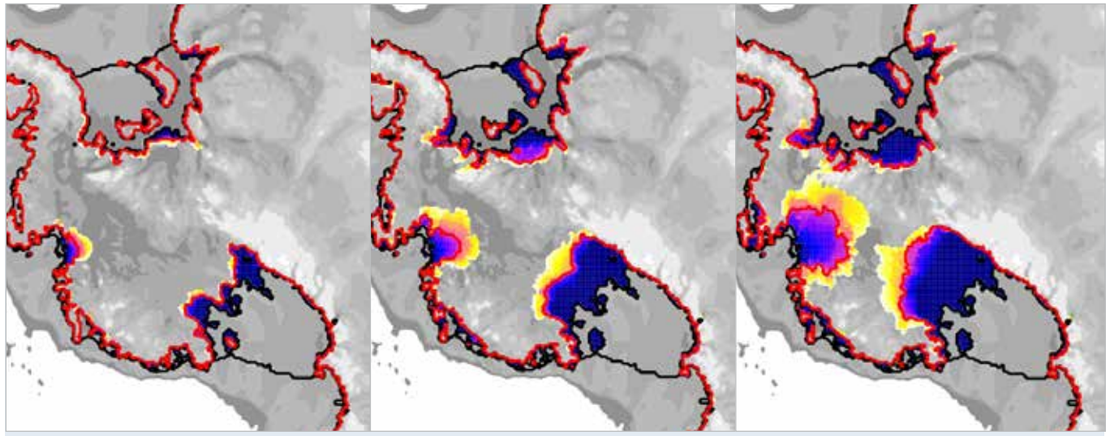

Simulated ice sheet retreat and grounding line position at 2100, 2200, and 2300 CE under the RCP 8.5 scenario (high emissions) using the PISM ice sheet model - Image: Dan Lowry

NATIONAL MODELLING HUB WORKING COLLABORATIVELY TO PREDICT CHANGES TO EARTH SYSTEM

The Antarctic Science Platform National Modelling Hub carries out numerical modelling to better understand the response of Antarctica to future warming, and to improve projections of the impact that Antarctic changes might have on the global earth system and the New Zealand environment.

Researchers from the ARC, NIWA and GNS Science hosted in the Antarctic Science Platform National Modelling Hub are working collaboratively on diverse and multidisciplinary projects ranging from changing ocean circulation, ice sheet dynamics, winds and marine ecosystems. Underpinning it all is data science, using powerful techniques such as machine-learning to more efficiently simulate the earth system and predict its behaviour.

Alexandra Gossart (ARC) is focused on simulating changes in atmospheric circulation and snow accumulation over Antarctica. She has set up a regional climate model with the capability to run at different spatial scales, allowing her to examine both large-scale patterns and small-scale phenomena that affect the distribution of snow and surface meltwater on the ice.

Alena Malyarenko (NIWA) and Stefan Jendersie (ARC) are examining regional ocean circulation and heat transfer around and under the Ross Ice Shelf to determine how the ocean influences melt rates of the ice above, ultimately producing better estimates of future ice loss and global sea-level rise.

Angela Bahamondes-Dominguez (NIWA) is developing a biogeochemistry model to assess the impact of climate on carbon cycling and plankton ecosystems in the Ross Sea, providing insight into how this important carbon sink might change in the future.

Mario Krapp and Dan Lowry (GNS Science) are simulating the Antarctic ice sheet under future warming scenarios. Using Dan's detailed physical process-based simulations of the ice sheet as a starting point, Mario has developed a statistical emulator to rapidly simulate different model parameter choices and to better assess uncertainty in sea-level rise projections.

As each of the model components are developed further, research in the coming years will shift focus to interactions and feedbacks between the different parts, working towards the long-term goal of simulating a fully-coupled system. Ultimately, this will allow the group to contribute new and important policy-relevant insights for this century and beyond.

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Traverse to Siple Dome, Antarctica - Photo: Kate McKensie

ANTARCTIC SCIENCE PLATFORM – AGAINST ALL ODDS – A SURPRISINGLY SUCCESSFUL YEAR WITH NO TIME TO WASTE!

This has been another exciting year for the Antarctic Science Platform team, despite the challenges thrown upon us all by COVID-19, we can celebrate important milestones.

As science activities in Antarctica were greatly reduced to safeguard the continent from COVID-19, Antarctica New Zealand completed the 2,500 kilometre Platform traverse to the Kamb Ice Stream and Siple Dome. The purpose of the traverse was to stage critical equipment for the ambitious Project 1 – Antarctic Ice Dynamics led by Richard Levy and Huw Horgan. Along the way, the team conducted radar surveys, snow measurements, and serviced the ice shelf mooring and weather stations. Onboard the *RV Tangaroa,* the Platform team successfully recovered and redeployed hydrographic moorings for Project 2 – Antarctic Ocean Mechanics to measure water formed in polynyas and conducted a vital survey on coastal ecosystems for Project 3 – Projecting Ross Sea Ecosystem Changes in a Warming World. A collaboration with fishing vessels allows Project 4 – Sea Ice and Carbon Cycle Feedbacks, a project co-led by Liz Keller, to collect air samples to measure the amount of atmospheric carbon taken up and ventilated by the Southern Ocean.

At home the SWAIS2C drill rig was commissioned and after a highly successful workshop with all partners, the International Continental Drilling Program (ICDP) proposal was resubmitted. Interpretation of data collected last year allowed for the exploration of the sub-glacial river beneath the Kamb Ice Stream (KIS-2) drilling target.

Our Independent Science Panel, chaired by Rob Dunbar (Stanford University), continues to be of vital importance, helping us to develop COVID-19 mitigation strategies and prioritise the most relevant and highest quality science goals. We also welcomed a new member, Sharon Stammerjohn, who accepted our invitation to join the distinguished group.

In November, we held our inaugural Platform conference in Wellington attended by >150 participants with science updates from our flagship research projects and facilitating 11 associated expert workshops. The meeting kicked off with the opening of the National Modelling Hub. The Hub, led by Nick Golledge and Liz Keller, is a collaboration between VUW, NIWA and GNS Science, to provide urgent, high priority policy-ready projections that inform local and national adaptation strategies. The conference provided another opportunity for our Expert Groups 'Future Projections' and 'Science to Policy Interface' to identify urgent policy priorities.

In partnership with the Deep South National Science Challenge we welcomed the joint DCS/ASP Kāhui, or Māori Advisory Panel. Chaired by Sandy Morrison and Aimee Kaio, the Kāhui is leading us to enrich and strengthen our science excellence through the incorporation of Mātauranga Māori (Māori knowledge) and Te Ao Māori (the Māori world view). The Kāhui finalised our Vision Mātauranga Strategy and held two successful and well attended workshops. The translation of the platform summary into te reo provides another exciting opportunity to extend our reach.

In the year ahead, it is important to maintain this strong momentum. While the world's attention has shifted to COVID-19, the climate crisis is marching on. Our collective actions over the next 5-10 years can lock us into severe climate change consequences that can play out over centuries to millennia. Antarctica's response to climate change has the potential to impact hundreds of millions of people this century. As governments around the world invest trillions of dollars into the revitalisation of economies, it is particularly important that we use this as an opportunity to help companies to transition to a green, sustainable future.

The Antarctic Science Platform funding model provides stability to weather this unexpected challenge and to grow expertise and capability to continue this important work. The ARC team is playing an critical role in this success along with its many partners in New Zealand and overseas.

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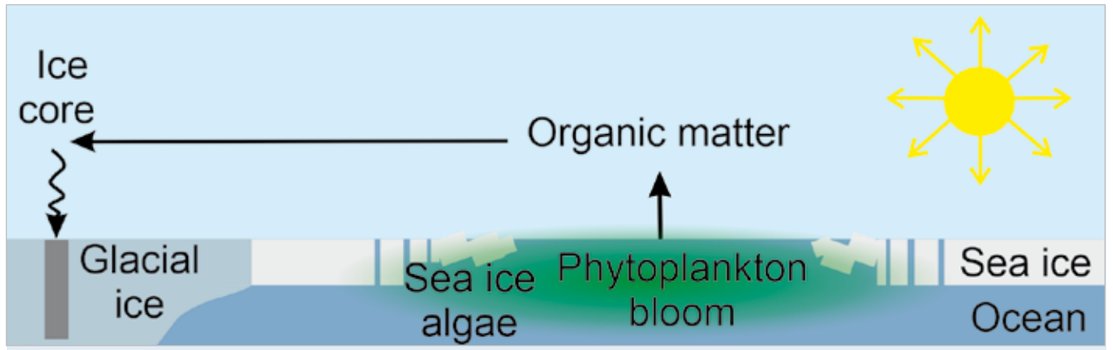

Large phytoplankton blooms form, triggered by sunlight, warmer temperatures and nutrient availability. Phytoplankton emit organic gases and aerosols into the atmosphere which are deposited in ice. By measuring the organic content in the ice we can understand how phytoplankton abundance and composition has changed over time - Schematic: Holly Winton

BIOMARKERS IN ICE CORES: A NEW ANALYTICAL CAPABILITY

Travel restrictions result in new biomarker analytical capability in New Zealand.

New analytical methods to quantify past phytoplankton change using novel biological markers (biomarkers), in Antarctic ice cores has been developed. Holly Winton originally planned to analyse biomarkers in ice core samples with colleagues in the UK as part of her Rutherford Postdoctoral Fellowship. Instead, as a result of COVID-19 travel restrictions, she established the capability here in New Zealand at the joint VUW - GNS Science Organic Geochemistry Laboratory and National Ice Core Facility with the help of instrumentation from the University of Waikato.

The primary interest in developing ice core biomarkers is to study past phytoplankton change in the Ross Sea region – a biological hotspot in the Southern Ocean. Phytoplankton are the pasture of the Southern Ocean and main energy source for Antarctic marine life. These plankton play a critical role in the global carbon climate cycle being responsible for half of the Earth's marine primary productivity, a process which converts carbon dioxide into organic molecules. However, observational records of phytoplankton are too short to understand how they may respond to a warming world.

Ice cores are important to extend the short observational record and understand what causes phytoplankton abundance and diversity to change in the past. The new ice core biomarker is based on fluorescence spectroscopy and gas chromatography-mass spectrometry. Using these techniques, we can understand how organic matter emitted into the atmosphere by phytoplankton has changed over time.

While Holly is primarily interested in phytoplankton and sea ice biomarkers, the new capability could provide other information about biomass burning, atmospheric pollution and fossil fuel consumption opening up a relatively unexplored field in ice core science.

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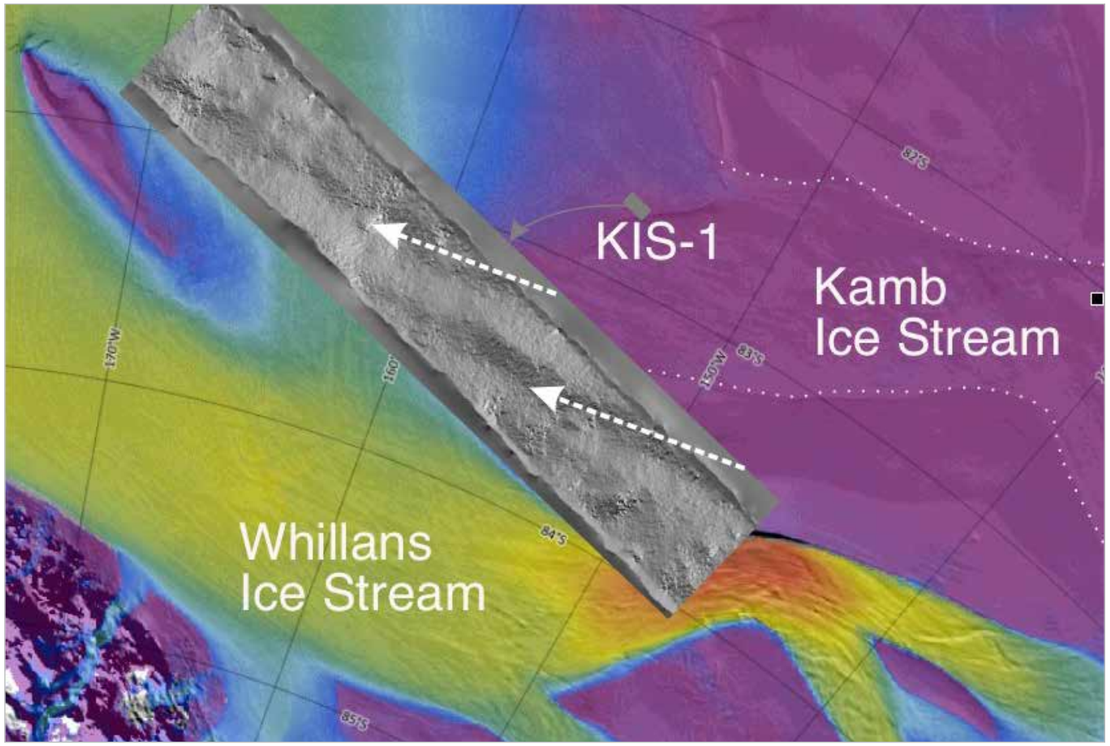

A ~5 metre long structure-from-motion rendering (greyscale) from Icefin video imagery of the sea floor showing metre-scale 'furrows'. The furrows align with the direction of flow of the Kamb Ice Stream in the past. The purple colouration shows it is now stagnant, unlike the Whillans Ice Stream
Image: Eric Rignot, Jeremie Mouginot, and Bernd Scheuchl

INTERNATIONAL COLLABORATION ON MASTERS THESIS

Theo Calkin is near completion of his MSc thesis on the sedimentation and stratigraphy of the Kamb Ice Stream site in Antarctica.

Theo's work is a collaborative venture that has benefitted from data and discussion with colleagues from NIWA (oceanography), GNS Science (clast petrography and radiocarbon data), NASA/Georgia Tech ('Icefin' remote submersible imagery) and University of Nebraska (diatom taxonomy). Theo's work has focussed on two aspects of the data that were collected at the Kamb Ice Stream (KIS) site in the 2019/20 field season.

Structure-from-motion is a type of image analysis that utilises a series of 2D images (like video frames) to render a feature of interest in 3D. After some initial attempts to reconstruct the sea floor at KIS-1 yielded results that looked distinctly non-geological, Theo was able to fine tune the software to highlight metre-scale furrows showing the path of the now stagnant Kamb Ice Stream's paleoflow. His analysis of ripple marks shows they were formed by currents flowing parallel to the Siple Coast. This orientation of the dominant tidal currents was confirmed by Craig Stevens (NIWA) who receives data from the oceanographic mooring hanging in the water column. Interestingly, the current speeds appear too slow to move sand-sized sediment today, so the bedforms are relict features formed possibly hundreds to thousands of years ago under different environmental conditions and preserved on the seafloor.

Our gravity corer collected half a metre of poorly sorted mud, sand and gravel (diamicton) sediment from below the seafloor. We applied the very latest ramped pyrolysis radiocarbon dating technique at GNS's Rafter Laboratory. The results showed the sediments were radiocarbon 'dead' and contained no dateable material. Diatoms and diatom fragments are common in the sediment. Their presence is often taken to indicate open water conditions since diatoms, as plants, need light to grow. However, these diatoms are many millions of years old (Miocene to Late Oligocene) and, along with the radiocarbon-free organic carbon, have likely been eroded from diatomaceous rocks now buried under the West Antarctic Ice Sheet. Their common presence at Kamb today does suggest that millions of years ago this area was a diatom-rich ocean basin. Moreover, the absence of uniquely Quaternary diatoms in our sediment opens up the possibility that the Ross Ice Shelf might not have collapsed in the last million years. Our forthcoming deep KIS drill core will help answer this question with a record of ice shelf stability that will, fingers crossed, span the last several million years.

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STUDENT SUCCESS ON FRIIS HILLS PROJECT

The completed PhD's of two ARC students answers some long-standing questions about Antarctica's glacial history, that are relevant to how it may change in the future.

Hannah Chorley joined Richard Levy and Tim Naish following her MSc degree at University of Bristol for six weeks of field work in late 2016, that involved drilling and describing ice-cemented, Miocene (16-14 million years ago) terrestrial glacial sediments in the Friis Hills, Dry Valleys, Antarctica. She then won a Victoria University of Wellington PhD scholarship to undertake a sedimentological study of the cores integrated with numerical ice sheet simulations, completing her PhD thesis and passing her oral exam in 2020.

Hannah's results provide new insights into the behaviour of the East Antarctic Ice Sheet (EAIS) when global temperatures were 4-5 °C warmer and atmospheric carbon dioxide was up to 600 parts per million. Hannah showed the EAIS was reduced in size, and that there had been multiple periods of growth and retreat of an alpine glacial system in the Transantarctic Mountains. These glaciations were associated with a warmer climate supporting small alpine lakes, and a now extinct tundra vegetation. She also documented progressive expansion of ice and growth of the EAIS as global climate cooled from about 14.5 million years ago.

Marjolaine Verret came from the University of Ottawa in 2017 on a Victoria University of Wellington scholarship to work with Warren Dickinson and Kevin Norton (SGEES) on cores from the Friis Hills project. She submitted her thesis in December 2020.

Marjo used geochemical proxies to characterize the sediments, organics, and ground ice from these cores to document 15 million years of changes in the high elevations of the McMurdo Dry Valleys. Her results suggest that the McMurdo Dry Valleys did not become permanently frozen during a major global cooling event 14 million years ago as previously proposed, and liquid water persisted long after this time. Indeed, the onset of polar aridity did not occur until 6 million years ago. Consequently, this region may be more susceptible to future climate change than anticipated.

Hannah and Marjo worked closely together on their projects, sampling the cores together, working in the Ice Core Facility at GNS Science, and discussing results. Together their work is being written up for at least six scientific papers in high profile international journals. Three have already been accepted for publication.

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Marjolaine Verret (left) and Hannah Chorley (right)

Brewster Glacier, New Zealand - Photo: Drew Lorrey

EXTREME MELT OF NEW ZEALAND GLACIERS IS MORE LIKELY TO OCCUR NOW THAN 100 YEARS AGO

Research published in *Nature Climate Change*, confirms extreme glacier melt is at least 10 times more likely under human-induced climate change.

The increase in frequency and severity of extreme glacier melt years is influenced by climate change. Specifically, our recent results point to increases in New Zealand temperatures of ~1°C over the past century, driven by rising greenhouse gas concentrations. These results were published in *Nature Climate Change* in August 2020.

This research, led by Lauren Vargo as part of her PhD in the ARC, developed a new framework for attributing extreme glacier melt years to natural or anthropogenic forcing. Combining extreme event attribution methods with glacier modelling, the new framework requires only short-term records of glacier mass change. This enabled Lauren and her colleagues to use direct mass balance measurements from Brewster and Rolleston glaciers, and proxies for glacier change from the End of Summer Snowline record.

The framework was applied to New Zealand glaciers, analyzing the anthropogenic influence on highest glacier melt years on record: 2011 and 2018. Results showed that extreme melt in 2011 was at least 6 times more likely with climate change (>90% confidence), and extreme melt in 2018 was at least 10 times more likely with climate change (>90% confidence). The study, made possible with funding and collaboration between the ARC's Brian Anderson, Ruzica Dadic, and Huw Horgan, Drew Lorrey (NIWA) and scientists from Australia.

This is only the second study to formally and directly link glacier melt to human-induced climate change. With multiple studies in agreement, it means we can be more confident in the link between anthropogenic forcing and glacier melt.

This confidence is especially important for inclusion in Intergovernmental Panel on Climate Change (IPCC) reports and guidance for policymakers.

Going forward, Lauren aims to apply this framework to glaciers around the world, analyzing the influence of climate change on extreme glacier melt today and in the future as temperatures continue to rise. As only short-term records of glacier change are needed, this global work can use measurements of annual glacier mass change for over 200 glaciers around the world.

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MAPPING GLACIER DEBRIS THICKNESS IN NEW ZEALAND

ARC researchers are combining drones, satellites, and machine learning to map debris thickness over New Zealand's glaciers.

Glacier debris is the rocky material that is often found atop glacier tongues in steep mountain ranges. Debris cover is particular common on some of New Zealand's largest glaciers in the Aoraki region, and this cover has increased over time. On the Haupapa/Tasman Glacier, debris covers the lower third of the ice, and varies in thickness. When it is thin this debris increases glacier melt, like wearing a black shirt on a summer day; while thicker debris reduces melt by insulating the glacier from the sun's heat. Therefore, to better understand how New Zealand's debris covered glaciers may respond to climate warming we need to know just how thick this debris cover is, and what its role is in enhancing or suppressing glacier melt.

ARC researcher Oliver Wigmore, as part of a Rutherford Postdoctoral Fellowship, has been deploying his custom-built drones equipped with thermal imaging cameras and a suite of onboard meteorological sensors to investigate these dynamic processes. Oliver has completed a series of sub-metre drone surveys of glacier topography and surface temperature, alongside extensive field measurements on the lower Haupapa/Tasman Glacier. He is combining these with satellite observations from new space-based sensors (e.g. NASA's ECOSTRESS sensor), alongside machine learning algorithms. These new methods are used to estimate debris thickness over the Haupapa/Tasman Glacier and the broader Aoraki region. The findings will help us to improve our understanding of these dynamic environments and the processes that control glacier evolution. Ultimately, these novel datasets will assist in our understanding of how these glaciers may change in a warming world.

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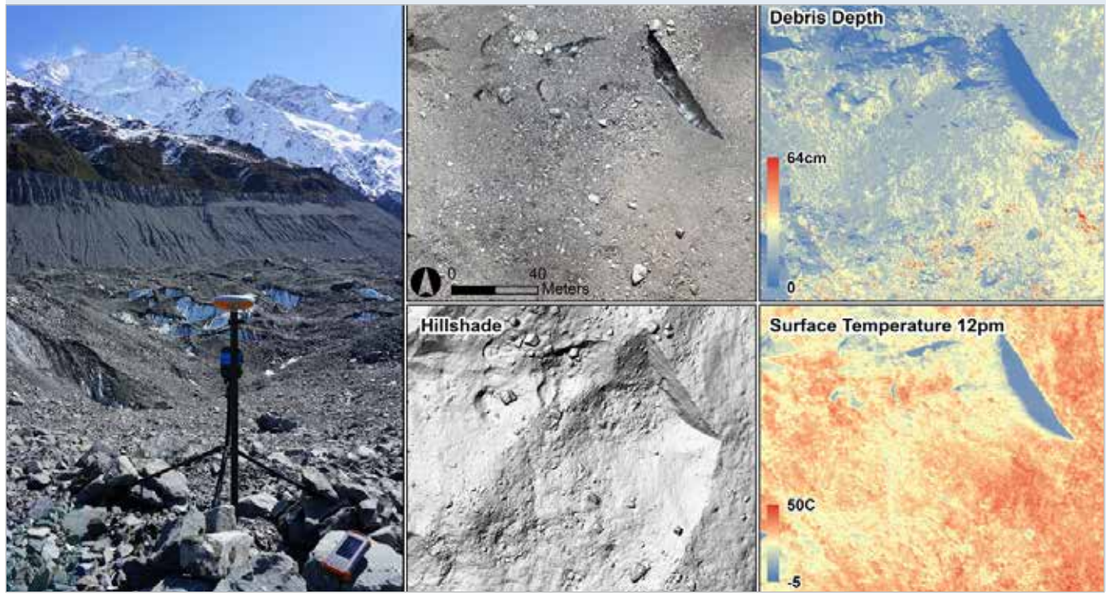
GPS survey and time lapse camera installation (left); drone derived imagery and digital elevation models shows surface features at extreme (cm) detail (centre); estimated debris thickness and mapped noon surface temperature at 20 cm spatial resolution (right)
Images: Oliver Wigmore



Leana Barriball deploying an instrument to map the saline wedge in the Wairoa River - Photo: Richard Levy

NZ SEARISE PROGRAMME MAKING GREAT WAVES

Another year of progress for Te tai pari o Aotearoa/NZ SeaRise programme reveals new sea-level rise data for Scott Base.

Our geodynamics team members have produced an all-important 'coastal strip' depicting vertical land movement with estimates of rates at which our coastline moves up or down during times between the big earthquakes. This information is critical for the location specific sea level projections we are producing with our colleagues Greg Garner and Bob Kopp (Rutgers University). We completed a study of sea-level rise at Pram Point, Antarctica through a collaborative project with Antarctica New Zealand to inform the Scott Base Redevelopment Project. It turns out that sea-level rise near Scott Base will be significantly less than the global average and may even drop if we fail to meet emissions targets and follow a high emissions pathway. This 'near field effect' is due to the decrease in local gravitational attraction of a shrinking Antarctic ice sheet on the ocean as well as crustal uplift that occurs as the ice sheet melts. Our ice sheet modellers contributed to several key international publications including the IPCC Special Report on the Ocean and Cryosphere and the Ice Sheet Model Intercomparison Project. Our programme was highlighted in a special issue on sea level published by the New Zealand Coastal Society. These publications offer an important venue to raise the local profile of our work.

Our students continue to make great progress on their research projects. Dan King (PhD, VUW) has now completed environmental surveys and collected sediment cores from Aramoana (Dunedin), Pāuatahanui (Porirua), Rangitoto (Waitemata), and Catalina Bay (Auckland) and is producing results that help us constrain historical sea-level rise. Zoe Heine (PhD, VUW) is well underway in her research into storytelling and sea-level rise. A big thanks to Zoe too for helping four students from Worcester Polytechnic Institute in the USA conduct a remote study into the efficacy of web-based sea level viewers in Aotearoa. Jesse Kearse (PhD, VUW) is working hard to resolve the influence of geodynamic processes on coastal movement. And finally, Leana Barriball (PhD, University of Waikato) started field work on her research that aims to examine the effect that sea-level rise will have on saline intrusion and inanga spawning sites up the Wairoa and Clive rivers in Hawke's Bay.

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HWD generators, Kamb Ice Stream, Antarctica - Photo: Tim McPhee

SCIENCE DRILLING OFFICE FORGING AHEAD DESPITE DELAYS

The ARC's Science Drilling Office (SDO) currently has one full time Operations and Field Engineer, Darcy Mandeno, while Alex Pyne continues on a part-time basis as an Antarctic Drilling Advisor.

2020 started successfully with Darcy and the drill team of Jane Chewings (SGEES, VUW), Hedley Berge, Tim McPhee, Sean Heaphy and Da Gong (Jilin University, China) finishing up a hot water drilling season at Kamb Ice Stream (KIS-1) after drilling through the Ross Ice Shelf and maintaining an open hole for nine days enabling multiple scientific objectives to be achieved.

The disruptive challenges of COVID-19 where yet to be realised, but by mid-2020 Antarctica New Zealand chose to defer the forthcoming Hot Water Drill (HWD) season at Kamb Ice Stream (KIS-2) to season 2021/22 when it was clear that the risks and impacts from COVID-19 were many and ongoing. The cancellation of the regular season US resupply ship to McMurdo Station added further logistic constraints on both the US and New Zealand Antarctic programmes.

The opportunity to make full use of this unexpected delay enabled Darcy and Alex's objectives to move from the HWD repairs and maintenance in anticipation for the KIS-2 season and place some focus on the new recently purchased Antarctic Intermediate Depth Drill (AIDD). HWD repairs and upgrades from the KIS-1 season continuing as a secondary annual task list. Most HWD items requiring repair coming back from Antarctica returned much later in the year due to significant delays by the March-April COVID-19 national shutdown and a widespread constraint on freight and shipping capacity, both nationally and internationally.

Alex Pyne having worked on scoping the AIDD rig, was able to finally receive the MP1000 arriving from the suppliers MultiPower of British Columbia, Canada in late November. The glass reinforced epoxy casing (GRE-casing) also arrived in the latter part of 2020 from Future Pipe Industries based out of Houston, Texas.

Additional work to get the AIDD rig and GRE pipe fit for Antarctic operations is to start in early 2021 with commissioning and assistance from Webster Drilling and Exploration Ltd., our industry partner providing additional support. Both Darcy and Alex kept busy with additional equipment requirements and supporting infrastructure that is currently in various stages of development, detail engineering design and construction. Heavier, bulky items expected to be shipped south later in 2021 to Scott Base for the KIS-3 drilling programme in 2022/23.

A winch used to support science groups over the past three seasons to recover shallow seafloor sediment samples, water column sampling for biological or oceanographic instruments proved at Kamb Ice Stream (KIS-1) to be a significant project risk. Several sub components failed due to the adverse environment the unit was expected to work in. After engineering analysis and with past season considerations the early decision was made to replace the winch with a higher specified winch supplied by Okeanus, a US company who have previously built winches for the Australian ice core programme. Delivery is expected in May/June of 2021.

With various drilling programmes in the near to middle term, both with the existing HWD asset and the new AIDD system, the SDO continues to find itself busy, while also navigating the evolving COVID-19 situation. 2021 is shaping up to be a very busy year and still remains to be seen just how these impacts will play out.

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TEACHING & SUPERVISION

Theo Calkin and Gavin Dunbar in Antarctica - Photo: Theo Calkin

OUR STAFF SUPPORT A WIDE RANGE OF COURSES BEING TAUGHT WITHIN THE SCHOOL OF GEOGRAPHY ENVIRONMENT AND EARTH SCIENCES

Our teaching contribution includes lectures in both undergraduate and graduate courses as well as supervision of graduate students enrolled with the School of Geography, Environment and Earth Sciences (SGEES). In 2020, our staff supervised 17 PhD and 3 MSc students, with seven students completing their thesis.

COURSES ARC STAFF TAUGHT IN

ESCI 111	The Earth System: An Introduction to Physical Geography and Earth Sciences
ESCI 132	Antarctica: Unfreezing the Continent
ESCI 201*	Climate Change and New Zealand's Future
ESCI 204	Petrology and Microscopy
GEOG 220	Hydrology and Climate
ESCI 241	Introductory Field Geology
ESCI 301*	Global Change: Earth Processes and History
GEOG 318	Quaternary Environmental Change
ESCI 452*	Earth History
ESCI 412*	Paleoclimatology
GISC 424*	Introduction to Remote Sensing
ENVI 520	Environmental Management

* An ARC staff member was the course co-ordinator

GRADUATE COMPLETIONS

Hannah Chorley (PhD)
Antarctic ice sheet and climate evolution during the mid-Miocene.
Supervised by Tim Naish (ARC) and Richard Levy (ARC/GNS Science).

Rachel Corran (PhD)
Tree ring reconstruction of modern atmospheric radiocarbon dioxide variability over the Southern Ocean.
Supervised by Nancy Bertler (ARC) and Jocelyn Turnbull (GNS Science).

William Gonzalez (PhD)
Evolution of the southern westerly winds in the middle latitudes of the Southern Hemisphere since the Last Glacial Maximum.
Supervised by Rewi Newnham (SGEES) and Gavin Dunbar (ARC).

Katelyn Johnson (PhD)
Holocene ice-ocean interactions in the Ross Sea and Adélie Land regions.
Supervised by Nancy Bertler (ARC) and Rob McKay (ARC).

Jamey Stutz (PhD)
Holocene thinning history of David Glacier, Antarctica.
Supervised by Kevin Norton (SGEES) and Andrew Mackintosh (formally ARC).

Laurine van Haastecht (PhD)
Subglacial conditions of the Kamb Ice Stream and its response to environmental change.
Supervised by Nick Golledge (ARC) and Huw Horgan (ARC/SGEES).

Marjolaine Verret (PhD)
Reconstructing 15 Myr of environmental change in the McMurdo Dry Valleys through permafrost geochemistry.
Supervised by Warren Dickinson (ARC) and Kevin Norton (SGEES).

SIGNIFICANT EVENTS

Photo: Prime Minister's Science Prizes Secretariat

WINNER'S OF THE PRIME MINISTER'S SCIENCE PRIZE

Led by the Antarctic Research Centre, the "Melting Ice and Rising Seas" team comprising 23 earth and social scientists from Victoria University of Wellington, GNS Science and NIWA has been awarded the New Zealand Prime Minister's Science Prize for 2019.

The Prize recognises worldclass, excellent research conducted in New Zealand, that has had impact and benefit. Due to COVID-19 the usual ceremony at Parliament was abandoned, and Prime Minister Jacinda Ardern announced the winner in a delayed event online via livestream on 30 June 2020 https://www.youtube.com/watch?v=hLe 43P1GboI.

ARC's, Tim Naish, led the team and says the impact of their work can already be seen around New Zealand.

"Our science on Antarctic ice melt and sea-level rise projections feeds directly into national policy and guidance on how to manage sea-level rise. We are working with central government, regional councils and local authorities."

While the Prize recognises research over the last five years, the team acknowledges the pioneering contribution of over 30 years by key team members, Peter Barrett (founding ARC Director) and Alex Pyne (world-leading polar science drilling specialist), which laid the foundations. Geological and ice drill core records acquired in the 80's, 90's and early 2000's by New Zealand-led international projects in the Ross Sea region have provided many fundamental insights, that are now central to our understanding of current concern over the future stability of Antarctica's ice sheets. Peter was well ahead of the time, when in 2004 he prophetically stated, "civilisation as we know it will be over by the end of the century if we don't change course", based on what he was learning from Antarctica.

Other ARC key team members included Nancy Bertler (Director of the Antarctic Science Platform), Lionel Carter, Nick Golledge, Huw Horgan, Richard Levy (Leader of the NZ SeaRise Programme), and current ARC Director Rob McKay, along with Brian Anderson, Ruzica Dadic, Warren Dickinson, Michelle Dow, Gavin Dunbar, Shaun Eaves, Liz Keller, Andrew Mackintosh (now Monash University), Darcy Mandeno, and Dao Polsiri. Other leading climate change researchers at the University were also key members of the team: James Renwick (Head of School of Geography, Environment, and Earth Sciences), Rebecca Priestley (Director of the Centre of Science in Society), and adaptation expert Judy Lawrence (Climate Change Research Institute). Nancy, Richard, and Liz also hold joint positions at GNS Science, and the other key team member, Rob Bell (NIWA), is New Zealand's leading coastal hazards expert.

During the past six years, members of the team have produced a plethora of papers, with 205 published in peer-reviewed journals, and an incredible list of 30 papers in the world's leading interdisciplinary scientific journals (e.g. *Nature* & *Science*). Three members of this year's winning team have also been recipients of Prime Minister's Science Prizes in the past. Rob McKay won the PM's MacDiarmid Emerging Scientist Prize in 2011, while Rebecca and James both secured the PM's Science Communication Prize, in 2016 and 2018, respectively. Tim, James, Nick and Judy have also been lead authors for the fifth and sixth IPCC Assessment Reports, while Andrew was lead author on the IPCC's Special Report on the Oceans and the Cryosphere. Judy and Rob Bell are also lead authors of the Ministry for the Environment's 2017 document on Coastal Hazards and Climate Change: Guidance for Local Government. The team's work highlights the profound effects of climate change on the Antarctic system and the potentially catastrophic effects of Antarctic ice loss on global sea level.

The prize comes with a $500,000 award. The majority of this ($400,000) has been invested into the ARC Endowed Development Fund and will be used to fund a PhD scholarship in perpetuity. The remaining $100,000 was split up evenly amongst the 23 members with suggestions they may like to spend it on lowering their personal carbon footprint.

Georgia Grant receiving her award at the prize ceremony
Photo: Royal Society Te Apārangi

FORMER ARC STUDENT WINS HATHERTON AWARD

Georgia Grant (now GNS Science) has received the Hatherton Award from the Royal Society Te Apārangi for the best scientific paper by a PhD student studying physical sciences, earth sciences or mathematical and information sciences at any New Zealand University.

Georgia's paper reveals the scale and implications for sea-level rise in New Zealand from Antarctic ice sheet retreat occurring under 2°C warming.

Georgia is a PhD graduate from the ARC, supervised by Tim Naish and Gavin Dunbar. Her research paper 'The amplitude and origin of sea-level variability during the Pliocene epoch', was published in the leading science journal *Nature*. She used a new method of analysing marine geological sediments to construct a global sea-level record for warm climates in the geological past that are similar to those we are projecting for coming centuries. The research shows approximately one third of Antarctica's ice sheets melted during the Pliocene epoch around three million years ago, causing sea levels to rise as much as 25 metres above present levels. Levels of carbon dioxide in the Earth's atmosphere were similar to today's levels of ~400 parts per million, and in response, temperature was two to three degrees Celsius warmer.

Georgia developed the new method of determining the magnitude of sea-level change as part of her PhD, through analysing the size of particles moved by waves and assemblages of fossilised microscopic shells that lived on the ancient seafloor. The method was applied to the geological archive from the Whanganui Basin on the west coast of New Zealand's North Island, which contains some of the best evidence anywhere in the world for global sea-level changes. The results were compared to model experiments to determine how changes in sea level at this site related to loss of ice in Antarctica.

Georgia's work was a fundamental breakthrough, as it used a globally unique drill-core record from the Whanganui backcountry that recorded past changes in water depth from marine sediments, now uplifted onto land by tectonic activity. To achieve her results, she developed a method of using changes in sediment grain size (smaller grain size equals deeper water as this setting is less influenced by high energy wave activity), incorporation of microfossil data (ecology of these microorganisms are dependent on water depth), and numerical modelling methods (mapping how grain size may vary with water depth and different wave climates).

These new sea-level estimates provide a target for testing the results from computer models and improving their ability to make accurate projections of the Antarctic contribution to global sea-level rise, in particular, the rates at which the ice sheets can melt in the future.

ASAHIKO TAIRA SCIENTIFIC OCEAN DRILLING RESEARCH PRIZE

Rob McKay has been awarded the Asahiko Taira Scientific Ocean Drilling Research Prize in recognition of outstanding, transdisciplinary research accomplishment in ocean drilling.

The Taira Prize is generously funded through the International Ocean Discovery Program (IODP) and is given in partnership between the American Geophysical Union (AGU) and the Japan Geoscience Union (JpGU). The Prize comes with an unrestricted award of USD $18,000. The prize reflects his work in stratigraphy, sedimentology, paleoceanography and paleoclimatology during the 12 years since finishing his doctorate at the University.

Rob has been involved in three large, multinational scientific drilling expeditions on the margins of Antarctica over the last 15 years, having participated in the ANDRILL McMurdo Ice Shelf project, IODP expedition 318 to Wilkes Land, and most recently as co-chief scientist for IODP expedition 374 to the Ross Sea. Rob's research findings from the ANDRILL IODP drilling expeditions, have been published in leading journals, such as *Nature*, *Nature Geoscience*, and *Proceedings of the National Academy of Sciences*; and include showing for the first time that large parts of the giant East Antarctic Ice Sheet are vulnerable to collapse if planetary temperature stays 2°C above preindustrial. This has major implications for global sea-level rise projections, as it is not just the West Antarctic Ice Sheet we now have to worry about.

Rob was also recognized for playing a critical leadership role for the international Scientific Ocean Drilling community, having being chairman of the Australia and New Zealand (ANZIC) IODP Science Committee; as well as a key organiser of workshops for shaping future drilling proposals in the SW Pacific/Indian Ocean as well as Antarctica. Most recently, he was an author on the Exploring Earth Through Scientific Ocean Drilling 2050 Science Framework, which outlines a >25 year ambition for future international ocean drilling collaborations.

Rob McKay on board the *RV Joides Resolution*, IODP expedition 374
Photo: Rob McKay

OTHER AWARDS AND APPOINTMENTS

In 2020 ARC staff and students were awarded the following:

Awards
Theo Calkin — Awarded New Zealand Post Antarctic Scholarship.

Matthew Tankersley — Awarded Antarctica New Zealand Doctoral Scholarship.

Promotions
Nick Golledge — Promoted to Professor scale in the 2020 Academic Promotion Round.

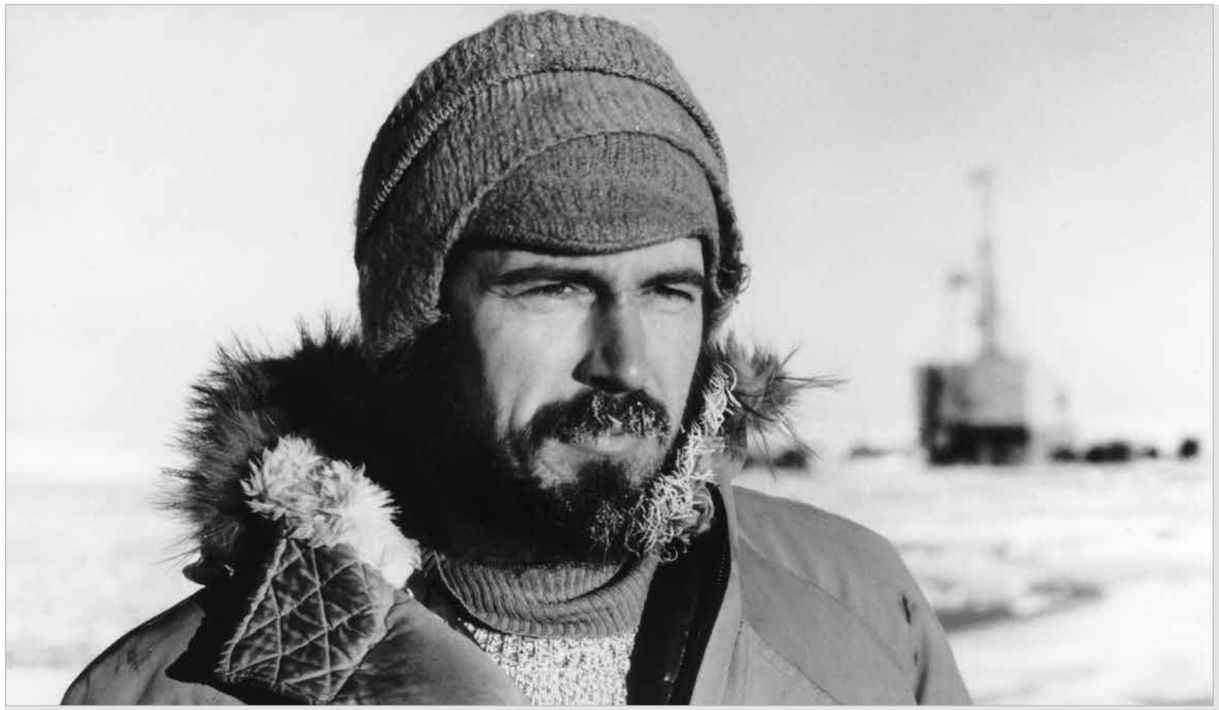
Huw Horgan — Promoted to Associate Professor scale in the 2020 Academic Promotion Round.

Appointments
Rob McKay — Appointed NZ/VUW representative on ANZIC governing council (Australia New Zealand Implementation Committee) for the International Ocean Discovery Program.

Tim Naish — Appointed Co-Chief of the new 8-year Scientific Committee on Antarctic Research (SCAR) Strategic Research Programme, INSTANT (INStabilities & Thresholds in ANTarctica).

Levan Tielidze — Appointed National Representative of Permafrost Researchers Young Network for Georgia (Caucasus).

Lauren Vargo — Appointed deputy head for the glaciers division of the International Association of Cryospheric Sciences (IACS).



Peter Barrett MSSTS-1 drillsite, Antarctica 1979/80

HONORING A LEGACY – THE PETER BARRETT SYMPOSIUM

On the 16-17 November, the Antarctic Research Centre hosted The Peter Barrett Symposium to celebrate his remarkable career.

Day one of the symposium was a fieldtrip to the Wairarapa looking at a series of fossiliferous limestones and mudstones that contain evidence of past changes in sea level and ocean temperatures relating to expansion and retreat of the ice sheets in Antarctica.

The following morning, we celebrated the career of Emeritus Professor Peter Barrett through a "This is Your Life" style timeline from his early years as a PhD student to filmmaker and climate "alarmist". Guests joined the event in person and from around the world via zoom – sharing their stories of Peter over the years. In the afternoon, the focus shifted to the "legacy" of Peter and the ARC highlighting the present research and future direction of the ARC and the impact Peter had on the Centre.

Peter Barrett grew up on a Waikato dairy farm and in his teens took up caving in the Te Kuiti district. He went on to study the Te Kuiti Limestone for his Master's thesis at Auckland University, and by chance in 1962 joined a University of Minnesota expedition to the Ellsworth Mountains in Antarctica. This led to a PhD at Ohio State University on the Gondwana strata of the Central Transantarctic Mountains, where he discovered the first tetrapod fossil in Antarctica, leading to the confirmation of the theory of plate tectonics. In 1970, Peter returned to New Zealand to take up a postdoctoral fellowship at Victoria University of Wellington, to continue their annual Antarctic expeditions. The following year he was appointed Senior Lecturer in Geology and the inaugural director of the Antarctic Research Centre, serving in this role from 1972 until 2007.

During that time, Peter led many Antarctic field parties involving both staff and graduate students and several ambitious drilling projects. Peter was aboard the first Deep Sea Drilling Project (DSDP; now the International Ocean Discovery Programme IODP) leg to Antarctica in 1972-73, which successfully collected cores in the Ross Sea, establishing the antiquity of Antarctic glaciation. From 1974 to 1999 Peter led a succession of offshore drilling projects culminating in the Cape Roberts Project recording Antarctic ice sheet dynamics and climate history from 34 to 17 million years ago. The successes and remaining questions led to the development of the ANDRILL Project.

Peter represented New Zealand as Geology delegate at meetings of the Scientific Committee on Antarctic Research (SCAR) from the early 1980s, becoming a steering committee member of the SCAR's ANTOSTRAT project in 1989, and co-founding SCAR's Antarctic Climate Evolution project in 2002. Peter served on the SCAR Group of Specialists on Environmental Affairs and Conservation from 1988 to 2002 and was also the first New Zealand delegate to the Antarctic Treaty System's Committee on Environmental Protection, serving from 1998 to 2003.

After the near collapse of the ARC in 2000 due to a proposed restructuring, Peter set his mind to building an enduring legacy. Part of that strategy involved philanthropy, enabling, in 2003, the launch of the inaugural S.T. Lecture in Antarctic Studies as well as a student exchange between the University of Alaska and the ARC supported by a generous donation from Singaporean philanthropist, Dr Lee Sung Tee. Peter also developed the ARC Endowed Development Fund, which was launched in 2004 by co-patron Barrie McKelvey. The other patron, Peter Webb, and Barrie were the sole members of the first Victoria University of Wellington Antarctic Expedition (VUWAE 1) that conducted some of the first geological mapping of the Dry Valleys in 1957. Peter's burgeoning reputation and that of the ARC attracted generous donations including, the $1 million donation from alumnus Alan Eggers in 2007. Through donations by alumni and supporters the Fund has now reached a total of $1.38 million. This legacy continues to grow and will support post-graduate student grants and two PhD Scholarships in perpetuity.

NZ climate strike, Wellington, 2019
Photo: Dao Polsiri

By 2006, 25 years after his first Op-Ed on future ice sheet melt from rising CO_2 levels, Peter realised the public were not recognising the disastrous consequences, so with geologist/cine photographer Simon Lamb, he developed a collaboration between Victoria University of Wellington, the University of Oxford, and film maker David Sington to produce *Thin Ice – The Inside Story of Climate Science.* This involved filming over 30 climate scientists in Europe, New Zealand, Antarctica and on the Southern Ocean and in the words of one review "put a human face on climate science". It was launched in 2013 at 200 locations covering all seven continents.

Throughout his career Peter has received several accolades. In 1963/64, the New Zealand Geological Survey Antarctic Expedition named a glacier in Antarctica after Peter. Barrett Glacier was officially recognised by the New Zealand Geographic Board in 2008. Peter was awarded a Polar Medal in 1978 and elected as a Fellow of the Royal Society of New Zealand in 1993. In 2001, Peter received the Premio Internazionale Felice Ippolito medal for Antarctic research from the Accademia Lincei (Italy), and in 2004 he received the Marsden Medal for his lifetime contributions to science in New Zealand. In 2006, he received the inaugural SCAR President's Medal for Outstanding Achievement in Antarctic science and was named Wellingtonian of the Year. In 2008, he was invited to be Patron of the New Zealand Antarctic Society. In 2010, Peter was awarded the New Zealand Antarctic Medal for services to Antarctic science and in 2011 he was made an Honorary Fellow of the Geological Society of London, a title only held by 70 people worldwide at the time. In 2020, Peter received the New Zealand Prime Minister's Science Prize as a key member of the "Melting Ice and Rising Seas" team.

Throughout the day as we paid tribute to Peter's outstanding contributions to earth science there were recurring words of a man who is, kind, patient, fun-loving, curious, optimistic and inspiring,

Peter with his Marsden Medal, 2004
Photo: Image Services

with a relentless perseverance, unselfish dedication, intellectual honesty, and social idealism, he is a strategic thinker, leader, advocate, mentor, and friend.

But in Peter's own words,

"I am described as a scientist but really I have always been an explorer.
And one that never really knew where he was heading.
I was just interested in understanding the earth, and working with like-minded people."

Peter Barrett, 2004

Tim Naish presenting at Congreso Futuro, Santiago
Photo: Tim Naish

ANTARCTIC SCIENCE AND SEA-LEVEL RISE IMPACTS FEATURE IN CHILE'S CONGRESO FUTURO

Tim Naish along with ex-Prime Ministers, Nobel Laureates, leading thinkers and scientists were invited to give TED-style talks at Chile's annual Congreso Futuro.

The Congress of the Future aims to open a national debate regarding the urgent need for Chile to have better science and technology, for the benefit of the society, economy and environment. Speakers were invited to share insights based on their experience. Tim spoke on climate change in an event in Santiago, visited the ALMA radio telescope array in the north of the country at 6000 metres above sea level in the Atacama Andes, and then travelled to Punta Arenas in the south to present a public talk on Antarctic ice sheet melting and sea-level rise along with Dr Marcelo Leppe, Director of INACH, the Chilean Antarctic Institute.

Chile is an incredible country geographically that spans the tropics to Antarctica, and the Pacific coast to the high Andes. It has many things in common with New Zealand. Environmentally, Chile sits astride a plate boundary and experiences natural hazards such as earthquakes and volcanic eruptions, it is 90% renewable for domestic electricity and is developing a plan to be net carbon zero by 2050. As a small nation it takes pride in being able to lead and influence on regional and global issues. It is also incredibly proud of its connection with Antarctica. It is endowed in natural resources, but its economy and social well-being are still weighed down by the legacy of years of extreme free market nationalism and oppression under the Pinochet dictatorship. The 2020 Congress was more important than ever as it was set on the backdrop of months of civil disobedience and riots following the social uprising that began on 16 October 2019.

The Congress is organised at the highest governmental level by the Chilean Senate and is largely co-ordinated and run by young people, the same young people who were also protesting in the uprising. With the government now consulting the people via referendum on a new constitution for the country, there was a real feeling of positivity. Tim and a selection of the invited speakers including, 2019 Nobel Prize Winner in Chemistry Professor Frances Arnold, were invited to meet with the President of Chile, Sebastian Pinera, and Science Minister Andrés Couve Correa. The meeting, which was held at the President's Palace in Santiago, discussed how science and technology could help improve the social and economic issues facing Chile.

S.T. LEE LECTURE IN ANTARCTIC STUDIES

The 17th Annual S.T. Lee Lecture titled "Tropical Tales of Polar Ice" was presented on 16 June, by Professor Andrea Dutton.

Andrea Dutton, Department of Geoscience, University of Wisconsin-Madison, USA, is a world-renowned expert on past climate and sea-level change. Her main research focus is to establish the behaviour of sea level and polar ice sheets during past warm periods to better inform us about future sea-level rise. One hallmark of Andrea's approach is the strong interdisciplinary nature of her work that blends field geology, geophysics, coral reef ecology, sedimentology, and geochemistry. Andrea is very active in communicating her research to the public and her combined impact within academia and in the sphere of public outreach has earned her numerous accolades, including being named as a fellow of the Geologic Society of America, as one of Rolling Stones' "25 People Shaping the Future", and most recently, as a MacArthur Fellow.

Andrea came to visit New Zealand in January 2020 as a United States Fulbright Scholar to work with ARC's Tim Naish, Rob McKay and Nick Golledge. Her captivating, S.T. Lee Lecture focussed on describing how her work on the impacts of sea level on fossil coral reefs on tropical islands has helped inform us about the dynamics of Antarctic ice sheet retreat during past warm periods and what that means for the future of coastlines around the world under future sea-level rise.

Andrea Dutton presenting the S.T. Lee Lecture
Photo: Image Services

(L-R) Alexandra Gossart, Mario Krapp, Alena Malyarenko; (insert) Angela Bahamondes-Dominguez - Photo: Image Services

ANTARCTIC SCIENCE PLATFORM NATIONAL MODELLING HUB FORMALLY OPENED

On 17 November, Hon David Parker, Minister for the Environment, formally opened the Antarctic Science Platform National Modelling Hub at Te Herenga Waka — Victoria University of Wellington.

The Antarctic Science Platform (ASP) National Modelling Hub was conceived in 2019 and established in 2020, building on long standing partnerships between GNS Science, NIWA, and the ARC at Victoria University of Wellington. Four Research Fellows have been employed and are co-located in the National Modelling Hub, hosted at the ARC, working alongside NZ SeaRise modellers Stefan Jendersie (ARC) and Dan Lowry (GNS Science). The Hub is managed by Nick Golledge and Liz Keller, Co-Chairs of the Future Projections Expert Group.

Hon David Parker at the opening ceremony
Photo: Image Services

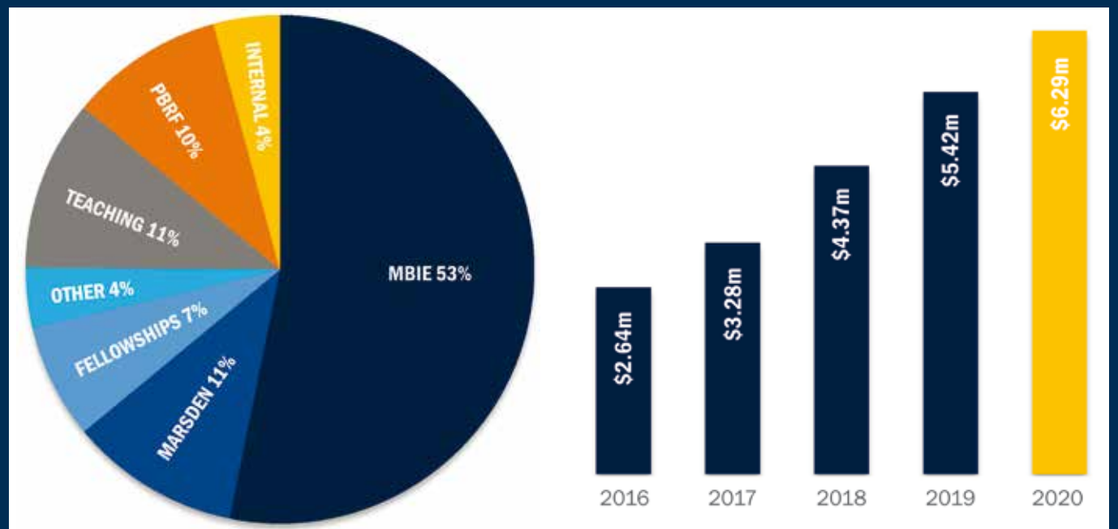
The Fellows share their time between their employing institution and the Hub. The Fellows are: Alexandra Gossart, regional climate modeller (ARC); Alena Malyarenko, process-scale ice shelf cavity modeller (NIWA); Angela Bahamondes-Dominguez, biogeochemical modeller (NIWA); and Mario Krapp, data scientist (GNS Science). Together the Fellows are focussing on future projections, and with researchers across the country and around the globe using computer simulations and equations to replicate different parts of the earth system, including the climate, the ocean and snow patterns, to predict what could happen in the future.

ASP Director, Nancy Bertler, says the Antarctic science community feels a strong sense of urgency to meet the challenges of climate change.

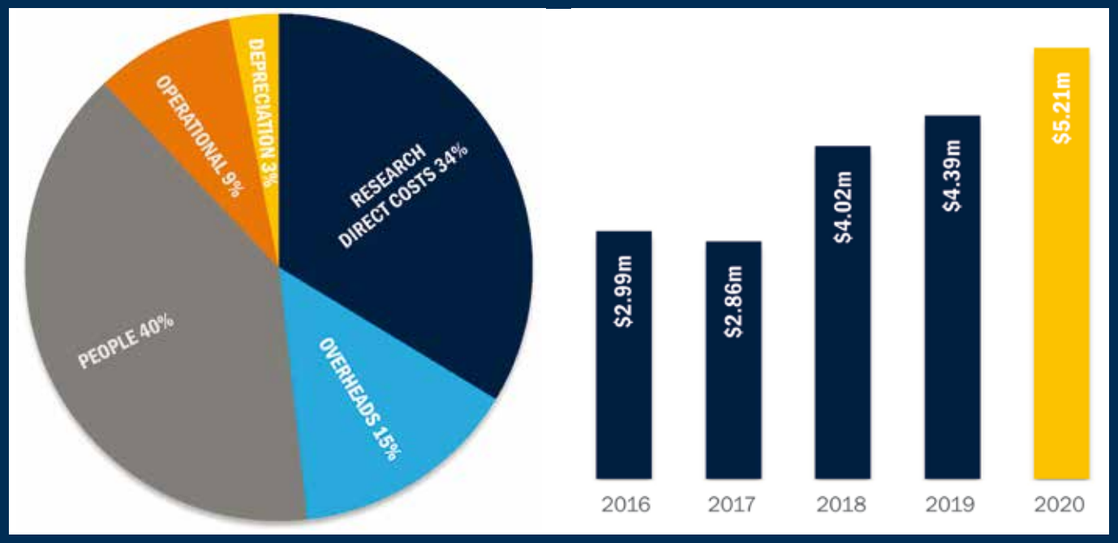
"Understanding how the Antarctic ice sheets, ocean and atmosphere interact, and how ecosystems will respond and in turn impact global carbon dioxide budgets, allows us to forecast and quantify impacts for humanity, but this requires international and interdisciplinary cooperation. The Modelling Hub is a new approach to bring together some of the brightest minds and leading experts in diverse fields to accelerate progress." she says.

FINANCIAL SUMMARY

REVENUE



EXPENDITURE



THE ARC GENERATED A SIGNIFICANT $740K SURPLUS IN 2020, AS REVENUE CONTINUES TO INCREASE

In 2020, the ARC generated $6.29m in revenue, contributed $756k of overheads to the University, and generated a $740k surplus for the Centre budget, with an overall expenditure of $5.21m.

The ARC finances include both a Centre budget and 49 grants held by the Research Trust of Victoria University of Wellington (RTV). Our consolidated revenue sources and expenditure areas as well as five year summaries are summarized in the charts opposite (all figures are exclusive of GST).

These charts combine the Centre budget that operates over the University financial year (January-December) and RTV budgets which operate over the life of the projects, as such, the year-end balances for revenue versus expenditure are often out-of-phase.

REVENUE

In 2020, 75% of ARC revenue came from external funding. The majoirty (53%; $3.3m) was from Ministry of Business, Innovation, and Employment (MBIE) contracts direct to VUW or via subcontracts with our research partners. Our other external funding came from five Marsden grants (11%; $679k), five Rutherford Fellowships (7%; $459k), and 'Other' national and international sources (4%; $240k) such as, the New Zealand Antarctic Research Institute, Intergovernmental Panel on Climate Change, Trans-Antarctic Association, and private donations held by the Victoria University of Wellington Foundation, and transferred to the Centre for the ARC Endowed Development Fund and Arnold Heine Antarctic Research awards.

The remaining 25% of our revenue comes from internal University sources. We received 11% from Teaching by way of a transfer of $682k from the School of Geography, Environment and Earth Sciences for teaching in their courses and a proportion of the supervision hours and graduate completion income.

PBRF (Performance-Based Research Fund) accounted for 10% ($580k) and is calculated by the University for funding it receives from the Tertiary Education Commission based on the quality rating of our staff.

The remaining 4% was from internal University grants.

EXPENDITURE

Our expenditure is divided between costs incurred directly within the RTV grants, and those from the Centre budget.

Research Direct Costs (34%; $1.75m) includes $891k of subcontracts to our research partners; $488k to support student fees and stipends; and $84k towards analytical costs. The remaining $292k went towards supporting costs such as fieldwork, consumables, and domestic travel.

The 15% overhead contribution to the Research Office and University was $756k.

The Centre direct costs included (40%; $2.07m) of people related costs associated with salaries, promotions, annual leave and superannuation. In 2020, the ARC also welcomed four new research fellows increasing our people costs from previous years.

The Centre's 9% ($464k) in operational expenses included; $214k to cover office and workshop space charges, $161k for research related costs that were either reimbursed from external organisations or transferred to grants, and $21k for IT related costs, leaving $68k for general operational costs such as office supplies, catering, printing, training courses, and domestic travel.

The final 3% ($164k) of expenditure is for depreciation of CAPEX equipment.

TWO ANTARCTICA NEW ZEALAND SCHOLARSHIPS AWARDED TO ARC STUDENTS

PhD student Matthew Tankersley and MSc student Theo Calkin were both awarded Antarctica New Zealand scholarships.

Antarctica New Zealand is committed to expanding New Zealand's Antarctic Science expertise and supporting the next generation of Early Career researchers by awarding these highly competitive scholarships.

Matthew Tankersley, has received an Antarctica New Zealand Doctoral Scholarship that includes $20,000 of funding over two years. He is using previously collected data to examine the depths to the sea floor and study the geology beneath the Ross Ice Shelf. The sea floor depth controls where warm ocean water can melt the ice shelf from the bottom. Matthew will also assess the amount of heat transmitted to the base of the ice sheet from the ground beneath. This heat melts the ice and the resulting meltwater lubricates the ice base, increasing the flow of ice from land onto the ice shelf. This research will give ice and ocean scientists the information they need to model how the Ross Ice Shelf will respond to a changing climate. An ice sheet is the ice that sits on land, while an ice shelf is an extension of the ice sheet that floats on the ocean. Matthew says he is honoured to receive the scholarship.

"I was fortunate enough to visit Antarctica in the 2019/20 season for eight weeks of field work on the Ross Ice Shelf. Living and working in that unique environment has given me a deep appreciation for Antarctic research and all the people contributing to it.

"I'm in the early days of my Antarctic-related research, but with the incredible support I've received so far from Antarctica New Zealand, Victoria University of Wellington, and GNS Science, I anticipate a long career in this field," Matthew says.

Theo Calkin, received the New Zealand Post Antarctic Scholarship for supporting his master's degree. This includes $10,000 of funding, for one year. He is using information collected from sediment cores from beneath the Ross Ice Shelf to better understand ice stream behaviour at the Kamb Ice Stream. The Kamb Ice Stream flows from West Antarctica into the Ross Ice Shelf almost 1000 kilometres from Scott Base at an area known as the Siple Coast. This research will contribute to understanding how the ice shelf will respond to climate change and contribute to sea-level rise.

Theo says the scholarship enables him to focus on the exciting job of analysing sediment from under the Ross Ice Shelf, which is one of the least studied areas on Earth.

"Having this support from New Zealand Post and Antarctica New Zealand at the early stages of my research career means a huge amount, and I'm grateful for the opportunity to further our understanding of how the Ross Ice Shelf will respond to climate change. "The Siple Coast ice streams play an important role in the stability of the West Antarctic Ice Sheet, so improving our understanding of the processes operating there is both important and rewarding," Theo says.

Matt Tankersley (left) and Theo Calkin (right) in Antarctica

NEW AUSTRALIAN INSTITUTE OF NUCLEAR SCIENCE AND ENGINEERING FUND

Jamey Stutz was the recipient of a newly established fund to support early career researchers.

In September 2020, Jamey received the first of a newly established Australian Institute of Nuclear Science and Engineering fund to support early career researchers working with researchers and analytical facilities at the Australia's Nuclear Sciences and Technology Organisation. The fund allows low-cost analyses for cosmogenic nuclides on glacial erratics and bedrock collected during the 2019-20 field season to the central Transantarctic Mountains. In collaboration with Kevin Norton and Shaun Eaves, this opportunity establishes a strategic partnership for cosmogenic nuclide analysis as part of the Antarctic Science Platform, Project 1.

Lisa Dowling, Dart Glacier, New Zealand - Photo: Lisa Dowling

ARC ENDOWED DEVELOPMENT FUND AWARDS

Through the generosity of alumni and collaborators the ARC Endowment Fund has reached over $1.36m.

The ARC Endowed Development Fund awards small grants of up to $4,000 to postgraduate students with research links to Antarctica. This provides students with opportunities that would not have otherwise been possible. Examples include; participation in international summer schools, the opportunity to work with collaborators in world-class analytical facilities, and the ability to travel to international conferences and workshops to present their scientific discoveries on a world-stage.

In 2020, the $400k award from Prime Minister's Science Prize (see page 23) was added to the fund to provide a PhD scholarship in perpetuity. The 2020 recipients were:

Hannah Chorley, Lisa Dowling, Lukas Eling, Florence Isaacs, Wei Ji Leong, Abhijith Ulayottil Venugopal, and Marjolaine Verret — to write-up papers on their respective research for submission to journals.

Fran Baldacchino, Theo Calkin, Steven Kesler and Sam Treweek, all received funding to attend the Geosciences Conference in Christchurch in November 2020.

ARNOLD HEINE ANTARCTIC RESEARCH AWARD

The 2020 recipient of Arnold Heine Antarctic Research Award went to recent PhD graduate and new Postdoctoral Fellow, Jamey Stutz.

Jamey Stutz has received the award to support ongoing analysis of glacial erratics and past glacial reconstructions in Antarctica. The Arnold Heine award will be used to support Claudia Moore, a third year undergraduate student, to assist Jamey in the arduous process of purifying rocks (cutting, crushing and separating) in preparation for chemical analysis. Claudia's work will allow efficient processing of a large collection of glacial erratics collected by Jamey and colleagues over past Antarctic field seasons. Additionally, Claudia has the unique opportunity to consider a range of sites that will form the core of her future honours research project. We are excited to mentor and train an emerging young scientist, and relieved to have extra help processing our rocks! Thanks again to Arnold and Jan Heine for their generous support for Antarctic research.

Jamey Stutz, sampling glacial erratics, Upper Byrd Glacier, Antarctica - Photo: Jamey Stutz

OUR ENGAGEMENT

Zach, a student from Waterloo School - Photo: Waverley Jones

THE ARC IS COMMITTED TO PRESENTING OUR RESEARCH AND KNOWLEDGE TO THE WIDER COMMUNITY

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ICEPerts Webinar One — 9 July, Tim Naish, *"Sea level rise."* https://www.antarcticscienceplatform.org.nz/updates/antarcticas-iceperts-a-webinar-series

Antarctic Society of New Zealand — 15 July, Tim Naish, *"Antarctic Chronicles (1): How humans are altering the course of natural climate change."* https://www.youtube.com/watch?v=DxJBsAM3ma0&t=1s

National Library — 27 July, Tim Naish, *"The currency of water."* https://natlib.govt.nz/events/the-currency-of-water-july-27-2020

Diplosphere and the British High Commission — 3 August, Tim Naish, *"Post COVID–Lets Build Back Better Conference."* https://www.diplosphere.org/event-info/lets-build-back-better-conference.

Public Talk and Panel Discussion — 5 August, Nancy Bertler, Nick Gollege, Judy lawrence, Richard Levy, Rob McKay, Tim Naish, "*Melting Ice and Rising Seas.*"

TrackZero-Auckland Live : Arts + Climate Innovation — 6 August, Tim Naish, *"Are artists creative disruptors."* https://trackzero.nz/projects-events/arts-climate-innovation-livestream-korero/

Hazel Glen College — 11 August, Lauren Vargo, "*Glaciers and climate change.*"

Antarctic Society of New Zealand — 19 August, Tim Naish, *"Antarctic Chronicles (3): Sea-level rise."* https://www.youtube.com/watch?v=NkSafwAZUmo&t=1s

Science Media Centre Savvy Course on Science — 28 August, Tim Naish.

The International School 'Skype a Scientist', Karachi, Pakistan — 26 September, Jamey Stutz, *"Introduction to Antarctic science."*

Tauira Film Competition. — 28 September, Nancy Bertler, *"Days of Ice: Antarctica Through Fresh Eyes."*

North Island Secondary School Geography Teachers Workshop — 28 September, Shaun Eaves, *"Reconstructing climate from glaciers."*

Keystone — 6 October, Tim Naish, Richard Levy, Ruzica Dadic, Lauren Vargo, Holly Winton, *"Why study the environment in New Zealand."*

Days of Ice: Kōrero on Ice Panel Discussion — 8 October, Nancy Bertler and Darcy Mandeno, Christchurch.

Transitional Cathedral Christchurch: Days of Ice Festival - For the Beauty of the Earth — 14 October, Tim Naish, *"Climate change."*

MOSAiC Expenditon Logbook — 23 October, Ruzica Dadic, "*Sledges and polar bears.*" https://www.slf.ch/en/about-the-slf/news/blogs/logbook/mosaic-expedition/sledges-and-polar-bears.html

Antarctic Through Fresh Eyes & Explorers Club Polar Film Fest — 18 November, Jamey Stutz.

Karori West Normal School — 18 November, Ruzica Dadic, "*Polar science and polar bears.*"

French Embassy — 11 December, Tim Naish, *"The Paris Agreement – Are we there yet."* https://www.francenzst.org/2020/11/24/fast-4th-annual-meeting/

OUR PUBLICATIONS

Patriot Hills, Antarctica - Photo: Chris Turney; Journal cover design: Alex Wing

PEER-REVIEWED PUBLICATIONS

Alevropoulos-Borrill, A.V., Nias, I.J., Payne, A.J., **Golledge**, N.R., Bingham, R.J. (2020). Ocean-forced evolution of the Amundsen Sea catchment, West Antarctica, by 2100. *Cryosphere* 14(4): 1245-1258. https://doi.org/10.5194/tc-14-1245-2020, 2020

Bohleber, P., Casado, M., Ashworth, K., Baker, C.A., Belcher, A., Caccavo, J.A., Jenkins, H.E., Satterthwaite, E., Spolaor, A., **Winton**, V.H.L. (2020). Successful practice in early career networks: Insights from the polar sciences. *Advances in Geosciences* 53: 1–14. https://doi.org/10.5194/adgeo-53-1-2020

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ANTARCTIC SCIENCE PLATFORM NATIONAL MODELLING HUB PUBLICATIONS

Angela Bahamondes Dominguez - NIWA:

Bahamondes Dominguez, A., Hickman, A.E., Marsh, R., Moore, C.M. (2020). Constraining the response of phytoplankton to zooplankton grazing and photo-acclimation in a temperate shelf sea with a 1-D model – towards S2P3 v8.0. *Geoscientific Model Development* 13: 4019–4040. https://doi.org/10.5194/gmd-13-4019-2020

Mario Krapp - GNS Science:

Baarsch, F., Granadillos, J.R., Hare, W., Knaus, M., **Krapp**, M., Schaeffer, M., Campen, H.L. (2020). The impact of climate change on incomes and convergence in Africa. *World Development* 126: 104699. https://doi.org/10.1016/j.worlddev.2019.104699

Beyer, R., **Krapp**, M., and Manica, A. (2020). High-resolution terrestrial climate, bioclimate and vegetation for the last 120,000 years. *Scientific Data* 7, 236. https://doi.org/10.1038/s41597-020-0552-1

Beyer, R., **Krapp**, M., and Manica, A. (2020). An empirical evaluation of bias correction methods for palaeoclimate simulations, *Climate of the Past* 16: 1493-1508. https://doi.org/10.5194/cp-16-1493-2020

Alena Malyarenko - NIWA:

Malyarenko, A., Wells, A.J., Langhorne, P.J., Robinson, N.J., Williams, M.J.M., Nicholls, K.W. (2020). A synthesis of thermodynamic ablation at ice-ocean interfaces from theory, observations and models. Ocean Modelling 154: 101692. https://doi.org/10.1016/j.ocemod.2020.101692

INVITED PRESENTATIONS

Golledge, N.R. (2020). Antarctic contributions to sea-level rise. *SCAR Open Science Conference,* virtual, 4 August 2020.

Golledge, N.R. (2020). Ice sheets and sea level: Past, present, future. *Nanyang Technological University (Singapore)*, virtual, 15 September 2020.

Golledge, N.R. (2020)., Emergence of critical climate states during the Plio-Pleistocene. *Massachussets Institute of Technology (MIT)*, virtual, 17 November 2020.

Johnson, K.M., **McKay**, R.M., Etourneau, J., Jiménez-Espejo, F., Albot, A., Riesselman, C., **Bertler**, N., **Horgan**, H.J., Crosta, X., Bendle, J., Ashley, K.E., Yamane, M., Yokoyama, Y., Pekar, S., Escutia, C., Dunbar, R. (2020). Holocene climate variability along the coastal margins of Adélie Land, East Antarctica. *AGU Fall Meeting,* virtual, 1-17 December 2020.

Levy, R. (2020). Te tai pari o Aotearoa - Future sea-level rise around New Zealand's dynamic coastline. *Antarctic Science Platform Conference*, Wellington, New Zealand, 19 August 2020.

Malyarenko, A., Wells, A.J., Langhorne, P.J., Robinson, N.J., Williams, M.J.M., Nicholls, K.W. (2020). Ice shelf-ocean ablation: A wide range in observations, a wider range in modelling. *The Oregon State University Seminar*, virtual, September 2020.

McKay, R. (2020). Colombia and Antarctica. *Latin America CAPE and the Embassy of Colombia to Australia and New Zealand Seminar*, Wellington, New Zealand, 10 December 2020.

Naish, T.R. (2020). *Chilean National Futures Congress "Congreso Futuro"*, Punta Arenas and Santiago, 15-17 January 2020.

Naish, T.R. (2020). New SCAR Strategic Research Programme – INSTANT. *SCAR Open Science Conference,* virtual, 3-7 August 2020.

Naish, T.R. (2020). The uncertain contribution of Antarctic ice sheets to future sea-level rise: Implications & impacts. *Antarctic Science Platform Conference*, Wellington, New Zealand, 19 August 2020.

Naish, T.R. (2020). Grand challenges in cryospheric science. *European Polar Science Week Conference*, virtual, 28 October 2020.

Naish, T.R. and Renwick, J. (2020)., CIIC and the Grand Challenge. *41st Meeting of the Joint Scientific Committee of the World Climate Research Program*, virtual, 18-22 May 2020.

Stutz, J., **Eaves**, S., Moore, C., Norton, K., **Lowry**, D. (2020). Deflated: Glacial thinning stories from the Transantarctic Mountains. *Antarctic Science Platform Conference*, Wellington, New Zealand 18-20 November 2020.

CHAIRED WORKSHOPS

Bertler, N. (2020). *Inaugural Antarctic Science Platform Conference*, Wellington, New Zealand, 18-20 November 2020.

Bertler, N., Colleoni F., and Fraser, C. (2020). SCAR mini-symposium - Antarctica in a warming world; regional changes, global consequences and future commitments. *SCAR Open Science Conference,* virtual, 3-7 August 2020

Eaves, S. (2020). Active Earth. *New Zealand Quaternary* e-Conference, virtual, 1 July 2020.

Eaves, S. and **Johnson**, K. (2020). Climate past and present. *Geoscience Society of New Zealand Annual Conference*, Christchurch, New Zealand, 22-25 November 2020.

Eaves, S., **Vargo**, L., and **Wigmore**, O. (2020). *New Zealand Snow and Ice Research Group Annual Workshop*. Matiu/Somes Island, Wellington, 3-5 February 2020.

Gossart, A. and **Vargo**, L. (2020). The cryosphere - Antarctica: Past, present and future. *Geoscience Society of New Zealand Annual Conference*, Christchurch, New Zealand, 22-25 November 2020.

Johnson, K. (2020). New Zealand history of ice and climate. *New Zealand Quaternary e-Conference*, virtual, 1 July 2020.

Levy, R., and **Horgan**, H. (2020). ASP Project 1 planning and implementation workshop. *Antarctic Science Conference*, Wellington, New Zealand, 18-20 November 2020.

Purdie, J. and **Vargo**, L. (2020). The cryosphere - Southern Alps and ice deformation to Antarctica. *Geoscience Society of New Zealand Annual Conference*, Christchurch, New Zealand, 22-25 November 2020.

Renwick, J., Robinson, N., Lamare, M., **Bertler**, N. (2020). Prioritisation of sea ice research - Opportunities, challenges and key deliverables workshop. *Antarctic Science Conference*, Wellington, New Zealand, 18-20 November 2020.

STUDENT ORAL PRESENTATIONS

Alevropoulos-Borrill, A., **Golledge**, N., **Lowry**, D., Cornford, S. (2020). Stabilizing and readvancing the grounding line of Pine Island Glacier. *Geoscience Society of New Zealand Annual Conference*, Christchurch, New Zealand, 22-25 November 2020.

Baldacchino, F., **Golledge**, N., **Horgan**, H., **Jendersie**, S., Stewart, C., Christoffersen, P., Bromirski, P. (2020). Investigating the seasonal dynamics of the Ross Ice Shelf, Antarctica using remote sensing data. *Geoscience Society of New Zealand Annual Conference*, Christchurch, New Zealand, 22-25 November 2020.

Calkin, T., **Dunbar**, G., Atkins, C., Harwood, D., Ginnane, C., Turnbull, J., Martin, A., Hulbe, C., **Horgan**, H. (2020). Sub-ice shelf sedimentary record at Kamb Ice Stream Grounding Zone, Siple Coast, West Antarctica. *Geoscience Society of New Zealand Annual Conference*, Christchurch, New Zealand, 22-25 November 2020.

Isaacs, F., Renwick, J., Mackintosh, A., **Dadic**, R. (2020). ENSO modulates summer and autumn sea ice variability in Dronning Maud Land, Antarctica. *Snow and Ice Research Group Workshop,* Somes Island, Wellington, 3-5 February 2020.

Johnson, K.M., **McKay**, R.M., Albot, A., Dunbar, R., Riesselman, C., Jiménez-Espejo, F., Etourneau, J., **Bertler**, N. (2020). Climate modulation of laminae deposition in Adélie Land, East Antarctica. *Geoscience Society of New Zealand Annual Conference*, Christchurch, New Zealand, 22-25 November 2020.

Khedim, N., Cécillon, L., Poulenard, J., Barré, P., Baudin, F., Marta, S., Gielly, L., Ambrosini, R., Rabatel, A., Dentant, C., Cauvy-Fraunié, S., Anthelme, **Tielidze**, L., Messager, E., Choler, P., Ficetola, G.F. (2020). Soil organic matter build-up during soil formation in glacier forefields around the world. *EGU General Assembly*, virtual, 4-8 May 2020.

Leong, W.J., and **Horgan**, H.J. (2020). October 20). DeepBedMap: A Super-Resolution Generative Adversarial Network for resolving the bed topography of Antarctica. *CEDSG Seminar Series*, virtual, 20 October 2020.

Stutz, J. (2020). Development of a virtual field experience: Byrd Glacier, Antarctica. *Engineering and Computer Graphics Multidisciplinary Workshop*, Wellington, New Zealand, 14 October 2020.

Stutz, J. (2020). Development of a virtual field experience: Byrd Glacier, Antarctica. *Computational Media Innovation Centre Interfaculty Collider Workshop*, 3 November 2020.

Stutz, J., Baroni, C., Colizza, E., Jamieson, S.R. Lee, J., Rhee, H., Sauli, C. (2020). Onshore to offshore glacial reconstruction of Terra Nova Bay, Western Ross Sea: A community work in progress. *SCAR Open Science Conference,* virtual, 3-7 August 2020.

Stutz, J., and **Eaves**, S. (2020). Thinning history of Byrd and Mulock glaciers: A preliminary field report. *SCAR Open Science Conference,* virtual, 3-7 August 2020.

Stutz, J., Mackintosh, A., Norton, K., Whitmore, R., Balco, G., Baroni, C., Casale, S., Jamieson, S., Jones, R.S., Salvatore, M.C. (2020). Rapid thinning of David Glacier in the recent geological past: Chronology and controls. *SCAR Open Science Conference,* virtual, 3-7 August 2020.

Stutz, J., Mackintosh, A., Norton, K., Whitmore, R., Jamieson, S.R., Jones, R.S. (2020). Controls on Holocene thinning of David Glacier, Antarctica. *New Zealand Quaternary Sciences e-Conference,* virtual, 1-2 July 2020.

Stutz, J., Mackintosh, A., Norton, K., Whitmore, R., Jamieson, S.R., Jones, R.S. (2020). Controls on mid-Holocene thinning along David Glacier, Antarctica. *AGU Fall Meeting,* virtual, 1-17 December 2020.

Stutz, J., and Wilson, T.J. (2020). Co-locating GPS, seismic and ice histories in Antarctica. *LIONESS Collaborative Workshop on Western Ross Sea and Amundsen Sea*, virtual, Korean Polar Institute, 14-15 May 2020.

Tielidze, L. (2020). The current state of the glaciers in the Caucasus Mountains. *Students in Polar and Alpine Research Conference (SPARC 2020)*, virtual, Brno, Czech Republic, 21-22 September 2020.

Tielidze, L. (2020). The history of glacier study of the Greater Caucasus and current state of observation. *18th Swiss Geoscience Meeting*, virtual, Zurich, Switzerland, 6-7 November 2020.

Tielidze, L., **Eaves**, S., Norton, K., Mackintosh, A. (2020). Comparison of Late Quaternary glacier extent from the Southern Alps and Greater Caucasus. *Snow and Ice Research Group Workshop,* Somes Island, Wellington, 3-5 February 2020.

Tielidze, L., **Eaves**, S., Norton, K., Mackintosh, A. (2020). Glacial history of the Ahuriri Valley, Southern Alps, New Zealand. *Trans-Tasman Quaternary Science e-Conference*, virtual, 1 July 2020

Tielidze, L., **Eaves**, S., Norton, K., Mackintosh, A. (2020). The Ahuriri Glacier during the Last Glacial Maximum, Southern Alps, New Zealand. *Students in Polar and Alpine Research Conference (SPARC 2020)*, virtual, Brno, Czech Republic, 21-22 September 2020.

Tielidze, L., **Eaves**, S., Norton, K., Mackintosh, A. (2020). Evolution of the Ahuriri Glacier during the Last Glacial Maximum, Southern Alps, New Zealand. *18th Swiss Geoscience Meeting*, virtual, Zurich, Switzerland, 6-7 November 2020.

Verret, M., **Dickinson**, W., Lacelle, D., Fisher, D., Norton, K., **Levy**, R., **Naish**, T. (2020). Meteoric ground ice in mid-Miocene permafrost: a paleo-temperature proxy, upper McMurdo Dry Valleys of Antarctica. *Geoscience Society of New Zealand Annual Conference*, Christchurch, New Zealand, 22-25 November 2020.

Verret, M., **Dickinson**, W., Norton, K., Lacelle, D., Christl, M., **Levy**, R., **Naish**, T. (2020). Presence of $^{10}Be_{met}$ in Miocene sediments challenges permanent polar aridity in the McMurdo Dry Valleys. *SCAR Open Science Conference,* virtual, 3-7 August 2020.

Whiteford, A. (2020). Surveying the shape of a subglacial channel with radio-echo sounding. *Snow and Ice Research Group Workshop,* Somes Island, Wellington, 3-5 February 2020.

STUDENT POSTER PRESENTATIONS

Leong, W.J., and **Horgan**, H.J. (2020). DeepBedMap: Resolving the bed topography of Antarctica with a deep neural network. *SCAR Open Science Conference,* virtual, 3-7 August 2020.

Moore, E., **Eaves**, S., and Norton, K. (2020). The glacial history of Rocky Top cirque, southeast Fiordland, New Zealand. *Geoscience Society of New Zealand Annual Conference*, Christchurch, New Zealand, 22-25 November 2020.

Pop, O. T., Răchită, I. G., Germain, D., Rikadze, Z., Holobâcă, I. H., Khuntselia, T., Alexe, M., Elizbarashvili, M., Gaprindashvili, G., Ivan, K., **Tielidze**, L. (2020). Tree-ring dating of colonized moraine surfaces in deglacierized areas of Greater Caucasus Mountains. *EGU General Assembly*, virtual, 4-8 May 2020.

Stutz, J., **Eaves**, S., and Norton, K. (2020). Thinning history of Byrd and Mulock Glaciers: A preliminary field report. *Geoscience Society of New Zealand Annual Conference*, Christchurch, New Zealand, 22-25 November 2020.

Tankersley, M., Bell, R., Black, J., Caratori Tontini, F., **Horgan**, H., Siddoway, C. Tinto, K. Wilner, J. (2020). Aeromagnetic data reveal broad basement structures under the Ross Ice Shelf, Antarctica. *Scientific Committee on Antarctic Research Annual Conference*, virtual, 3-7 August 2020.

Tankersley, M., Bell, R., Black, J., Caratori Tontini, F., **Horgan**, H., Siddoway, C. Tinto, K. (2020). Broad Basement Structures Under Antarctica's Ross Ice Shelf Revealed from Aeromagnetic Data. *AGU Fall Meeting*, virtual, 1-17 December 2020.

Tankersley, M., **Horgan**, H., Caratori Tontini, F., Siddoway, C. Tinto, K. (2020). Constrained geopotential modelling of the ocean cavity and geology beneath the Ross Ice Shelf. *Geoscience Society of New Zealand Annual Conference*, Christchurch, New Zealand, 22-25 November 2020.

Tielidze, L., **Eaves**, S., Norton, K., Mackintosh, A. (2020). Reconstruction of Late Quaternary glaciation in the Ahuriri River valley, New Zealand, based on geomorphological mapping and cosmogenic 10Be data. *Nordic Branch Meeting 2020*, virtual, Copenhagen, Denmark. IGS. 11-13 November 2020.

Tielidze, L., **Eaves**, S., Norton, K., Mackintosh, A. (2020). Glacial geomorphology of the Ahuriri River valley, central Southern Alps, New Zealand. *Geoscience Society of New Zealand Annual Conference*, Christchurch, New Zealand, 22-25 November 2020.

OUR PEOPLE

Rob McKay
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Stratigraphy & sedimentology

Brian Anderson
Associate Professor
Glacial modelling

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Emeritus Professor
Antarctic climate history

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Ice core climatology

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Holly Winton
Postdoctoral Fellow
Ice core biomarkers

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POSTGRADUATE STUDENTS

Alanna Alevropoulos-Borrill	PhD	Ice sheet modelling
Francesca Baldacchino	PhD	Remote sensing
Hannah Chorley*	PhD	Antarctic climatology
Jay Cockrell	PhD	Antarctic paleoclimate
Rachel Corran*	PhD	Past & future emissions
William Gonzalez*	PhD	Palynology
Florence Isaacs	PhD	Antarctic climatology
Katelyn Johnson*	PhD	Ice core climatology
Wei Ji Leong	PhD	Machine learning
Ihanshu Rane	PhD	Antarctic foehn winds
Jamey Stutz*	PhD	Glaciology
Matthew Tankersley	PhD	Geopotential modelling
Levan Tielidze	PhD	Glaciology
Laurine van Haastrecht*	PhD	Antarctic glaciology
Marjolaine Verret*	PhD	Permafrost geochemistry
Arran Whiteford	PhD	Subglacial hydrology
Yaowen Zheng	PhD	Antarctic climatology
Joanna Borzecki	MSc	Glaciology
Theo Calkin	MSc	Glaciomarine geology
Emily Moore	MSc	Glacial history

*thesis submitted for examination in 2020

ASSOCIATED RESEARCHERS

Cliff Atkins	Senior Lecturer in Earth Sciences	Sedimentary processes and environments
Michael Hannah	Associate Professor in Earth Sciences	Marine palynology
Judy Lawrence	Senior Research Fellow	Climate change decision-making and adaptation
Kevin Norton	Associate Professor in Geography	Geomorphology and geochemistry
Rebecca Priestley	Associate Professor - Science in Context	Antarctic science history
James Renwick	Professor in Physical Geography	Atmospheric circulation
Rhian Salmon	Deputy Director - Science in Society	Science communication
Tim Stern	Professor in Geophysics	Solid earth geophysics and Transantarctic Mountains

OTHER VUW ACADEMICS WITH ANTARCTIC INTERESTS

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

LIST OF COLLABORATORS

NATIONAL COLLABORATORS

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Meridian Energy
New Zealand eScience Infrastructure (NESI)
NIWA
Oceanum
University of Auckland
University of Canterbury
University of Otago
University of Waikato
Webster Drilling and Exploration Ltd.

INTERNATIONAL COLLABORATORS

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Alfred Wegener Institute (Germany)
Australian Antarctic Division
The Australian National University
Australian Nuclear Science and Technology Organisation
Australian Institute of Nuclear Science and Engineering
Berkeley Geochronology Centre (USA)
Binghamton University - State University of New York (USA)
British Antarctic Survey (England)
Central Washington University (USA)
Chinese Academy of Meteorological Sciences
Chinese Academy of Sciences
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Istituto Nazionale di Geofisica e Vulcanologia (Italy)
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RICE team, Antarctica - Photo: Nancy Bertler

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