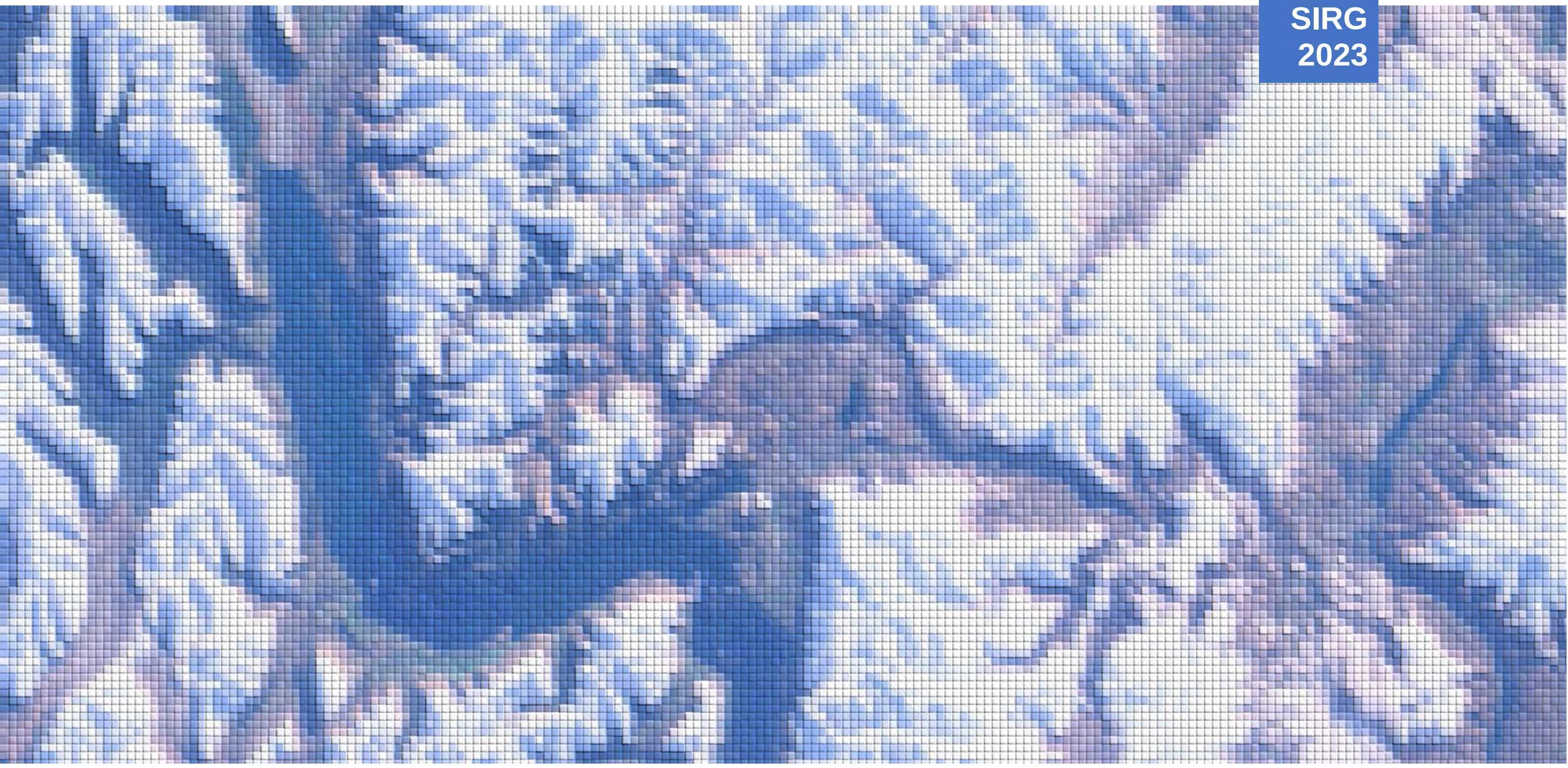
SIRG
2023



SIRG 2023 Annual Workshop

PROGRAMME AND ABSTRACTS

FEBRUARY 9 – 11, 2023, CORONET PEAK, QUEENSTOWN, NEW ZEALAND

Lake ice of Lake Fryxell in Taylor Valley. Photo Credit: Marte Hoftseenge.

The 2023 SIRG organising committee began life as the 2022 SIRG organising committee, and consists of Todd Redpath, Martin Forbes, Holly Still, Nariefa Abrahim and Nicolas Cullen. We also thank Jim Salinger for assisting in the early stages of planning.

Todd, Martin and Holly are on site for the duration of SIRG 2023. Look for us if you have any questions or concerns at any stage.

Cover image: Stylised rendering of RGB Sentinel-2 image captured of the Whakatipu Basin, 16/07/2022. Copernicus Sentinel data 2022.

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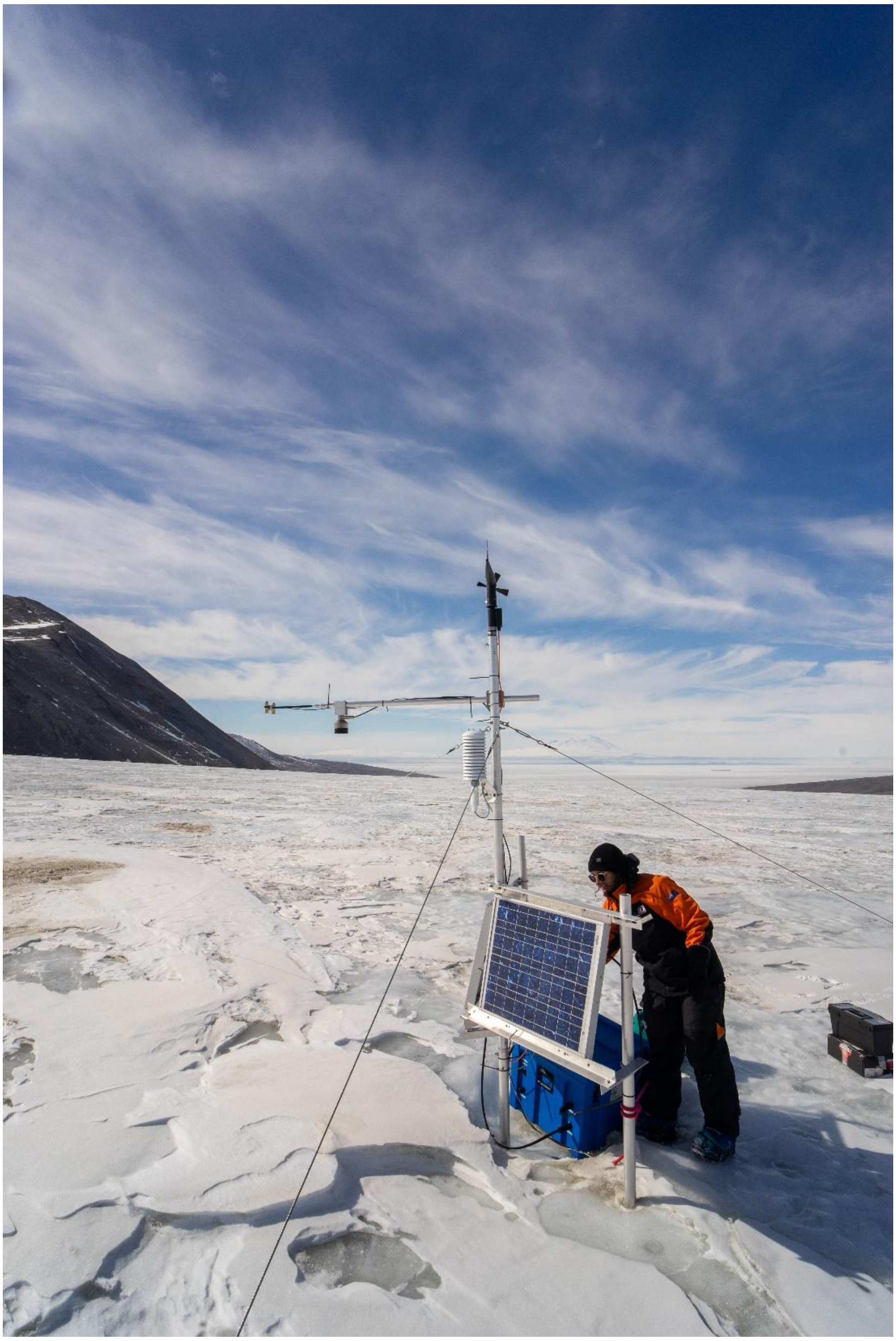

Tamara Pletzer downloading data from an AWS at Commonwealth Glacier, 2022/2023 field season. Photo credit: Marte Hofsteenge.

Welcome

Nau mai, haere mai, welcome to the 19th Snow and Ice Research Group (SIRG) Annual Workshop. It is worth noting that 2023 marks 20 years since the inaugural SIRG workshop, and if it weren't for the COVID-19 induced interruption of 2022 we would be celebrating the twenty-meeting milestone (next year, eh). This year, SIRG returns to the Whakatipu basin, a location where many themes of our research are ever-present. Our venue, Coronet Peak, is steeped in the history of New Zealand snow sports and tourism. Mechanised lift access began here in 1947. Development continues today, with technology playing an ever-increasing role in maintaining skiable pistes in the face of Aotearoa New Zealand's "variable" snow climate and into an uncertain future.

From the slopes of Coronet Peak, an impressive view is offered across the Whakatipu Basin, where the built environment of Tāhuna/Queenstown is spread across the relics of the Pleistocene Glaciations. The Kawarau River drains Whakatipu-wai-Māori/Lake Wakatipu, which in turn is fed by the hukawai of the glaciers of Pikirakatahi and Te Awa Whakatipu/Dart River, and the seasonal snow that cloaks the surrounding mountain ranges through the winter. Ngāi Tahu tradition tells of the formation of Whakatipu-wai-Māori when the giant tipua (ogre) Matau was burned in his sleep while the northwest wind blew. The lake bed formed in the hollow where his body lay, and was filled with water from the snow that was melted off the surrounding mountains by the inferno.[1]

Across the basin lie the Remarkables, the iconic mountain range drained to the south by Wye Creek, the site of one of several early (1930s) hydro-electric power stations in the region operating within snow-dominated catchments[2]. As the Kawarau joins the Clutha/Mata-au, the waters of Whakatipu continue to contribute substantially to meeting the energy needs of Aotearoa New Zealand.

The mountain roads and ski area infrastructure of the Queenstown Lakes District bring appealing field sites for cryospheric research within relatively easy reach. When "lack of observations" becomes, cliché in scientific discussions of the state of our alpine environments, we shouldn't forget that this region is home to organisations, businesses and people who have been making their own observations for years to decades. There is much to contemplate here for the cryospheric scientist, whether it be the past, current, or future role of snow and ice within the local environment, or the methods and theories that can be developed and tested here for application elsewhere. We hope that you find the 2023 SIRG workshop to be a stimulating and productive meeting. We are especially excited about the opportunity for networking and sharing of exciting science by our student researchers, a strength of SIRG that we hope to maintain.

Todd, Martin, Holly, Nariefa and Nicolas

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[1] Ngāi Tahu Claims Settlement Act 1998, Schedule 75, Statutory acknowledgement for Whakatipu-wai-māori (Lake Wakatipu)

[2] Wye Creek (established 1936) was decommissioned in 2008. The upper and lower Roaring Meg stations (both established 1936), located in and above the Kawarau Gorge, continue to operate.

Acknowledgments

The annual SIRG workshops rely on the generous support of our sponsors. Support for the 2023 workshop has been provided by:

- Coronet Peak – venue support
- NIWA – financial support
- Antarctica New Zealand – financial support
- Split'n2 – student talk prizes
  www.splitn2.com
- Paul Hersey – student talk prizes

About SIRG

The annual meeting of the New Zealand Snow and Ice Research Group provides an opportunity to meet and discuss our common interest in snow and ice research.

The New Zealand Snow and Ice Research Group (SIRG) are those people who have registered on the "SIRG" mailing list. SIRG maintains a website at: http://sirg.org.nz/, the mailing list can be joined by request via the website.

SIRG is the New Zealand branch of the International Glaciological Society: http://www.igsoc.org/.

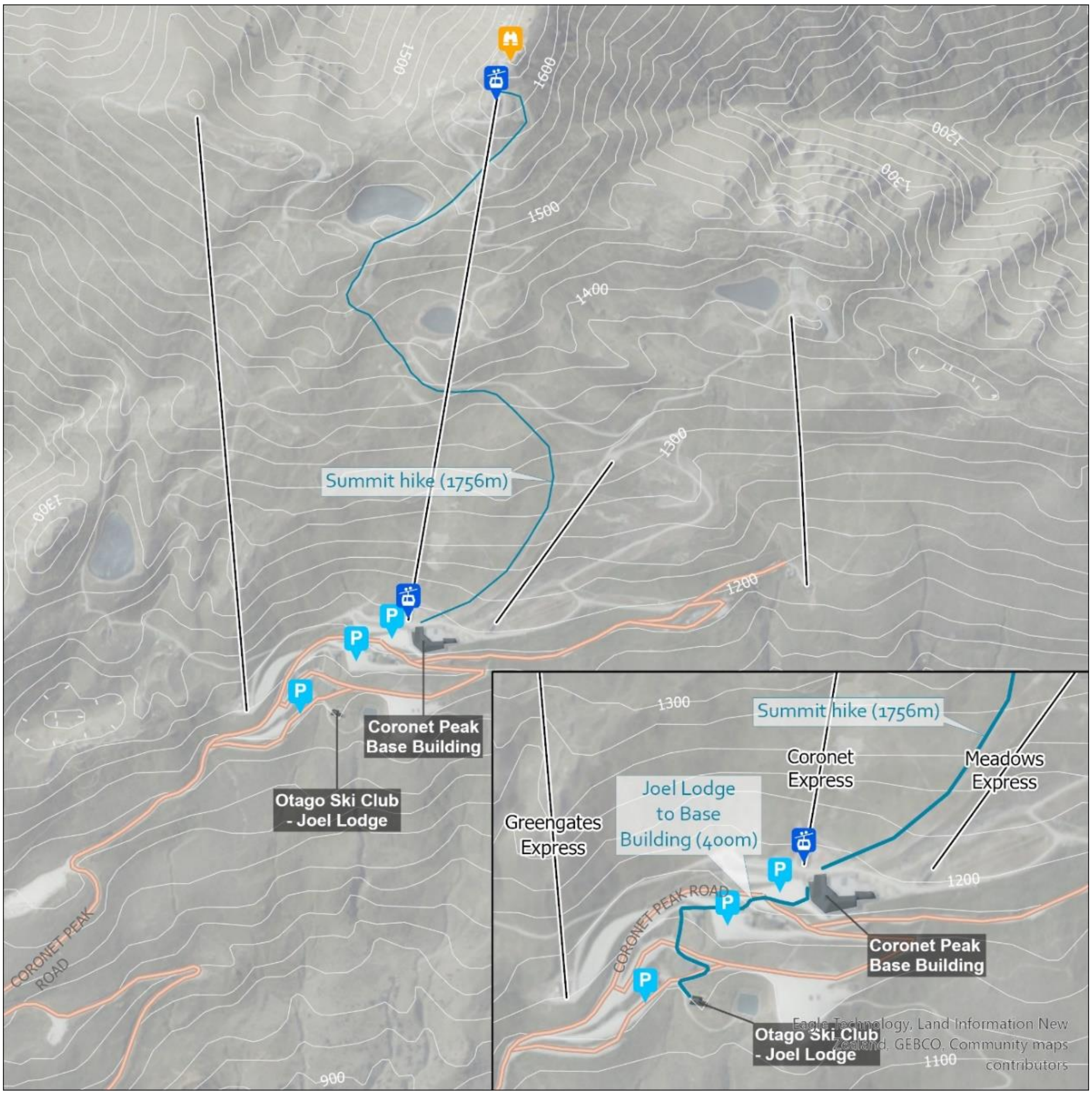
SIRG maintains an on-line bibliography of New Zealand snow and ice research publications: https://www.zotero.org/groups/sirg/items.

Ski touring on the Crown Range, above the Whakatipu Basin, July 2022. Photo credit: Todd Redpath.

Venue Information

The 2023 SIRG workshop is held at Coronet Peak, a ski area located in the Whakatipu Basin. Coronet Peak is easily accessible by New Zealand standards, with a sealed road to the base area. Driving time is approximately 20 minutes from Queenstown or Arrowtown, and 30 minutes from Queenstown Airport.

Workshop sessions will be held in the Peak Club lounge of the Coronet Peak base building. The Peak Club is accessed through the café on the upper level of the base building. Meals for attendees and accommodation for those staying on site are located at the Otago Ski Club's Joel Lodge. Allow ten minutes to walk between Joel Lodge and the base building. There is ample carparking available at Coronet Peak during the summer. The best carparking for Joel Lodge is in carpark 5. Parking is also available adjacent to the base building and in carpark 1. Please follow any signage or the directions of Coronet Peak staff. WiFi will be available on site.



Map of Coronet Peak showing the main base building, car parks, and Joel Lodge.

Coronet Peak

Commercial lift accessed skiing began at Coronet Peak in 1947, and the mountain now operates for mountain biking and sightseeing throughout summer. This means that the café is open and barista coffee is available to purchase on site! On Thursday evening the café/bar is open until 8 pm, perfect for socialising on our first evening. The Coronet Express Gondola operates until 8 pm on Thursday and 4 pm on Friday – a return sightseeing trip to the summit costs $35 and can be purchased at the base building or at www.coronetpeak.co.nz. There is also a walking trail to the summit (approx. 1.8 km and 450 vertical metres each way). On a clear day the view from the top is worth the trip, with Aoraki visible to the north.

Winter view of Coronet Peak base area, with annotations showing the main base building and Joel Lodge. Photo credit: Gregor Macara.

Joel Lodge

Joel Lodge is owned by the members of the Otago Ski Club and was established in the 1950's as the club relocated from the Rock and Pillar Range (much closer to Dunedin) to Coronet Peak to take advantage of more reliable snow and rapidly developing infrastructure. The Lodge is situated on the right-hand side of Carpark 5. Please note the following guidelines from the Otago Ski Club:

- Car parking is available on the left side of Vincent Lodge – in Carpark 5.
- The driveway down to the Lodge must be kept clear at all times, for NZSKI staff to access their ponds.
- The Lodge facilities include drying room, kitchen, lounge, dining room & ski repair room/games room.
- Sleeping quarters are large, shared bunk rooms. There are two family rooms which sleep two adults and two children.
- No luggage in bunkrooms (fire requirement) – lockers are provided in the changing rooms for bags, clothes etc.
- There is a blue light switch just inside the bunkroom doors for night use. It puts on a dim light instead of the main lights, so as to not wake other people.
- Please provide your own sleeping bag and pillow slip (pillow provided).
- To ensure the Lodge aligns itself with the wastewater requirements of NZSKI, the Lodge provides liquid shower body wash, shampoo, conditioner and liquid hand wash. We would strongly recommend that you use these products, unless you have skin allergies.

COVID-19 considerations

We are conscious that SIRG 2023 takes place during a time of lingering uncertainty in the context of COVID-19. In hosting an in-person workshop, we are taking steps to ensure that the workshop is a safe and comfortable experience for all attendees. We encourage all attendees to take a rapid antigen test (RAT) before travelling to SIRG. Mask wearing is welcome at SIRG 2023 and we will have surgical masks available for the duration of the workshop, along with hand sanitiser and RATs. We will aim to provide room for adequate distancing amongst participants, and to ensure sufficient ventilation at all times. As far as the weather allows, we encourage attendees to take advantage of outdoor spaces during the breaks.

Programme

Thursday, February 9, 2023		
13:30-14:00	**SIRG 2023 welcome and introduction**	
14:00-15:00	**Session 1: Snow**	
14:00	Todd Redpath *University of Otago*	Satellite observations of snow depth to support hydrological modelling in Aotearoa New Zealand
14:15	Tamara Pletzer* *University of Otago*	Modifying a snowpack model to simulate glacial melt processes in the McMurdo Dry Valleys
14:30	Jono Conway *NIWA*	Improving the representation of seasonal snow hydrology within the New Zealand Water Model
14:45	Blair Fitzharris *University of Otago*	Seasonal Snow, Volcanic Super Eruptions and Electricity Crises
15:00-15:45	Break	
15:45-16:45	**Session 2: Southern hemisphere glaciers**	
15:45	Heather Purdie *University of Canterbury*	Influence of crevasses on air temperature over a maritime glacier
16:00	Marte Hofsteenge* *University of Otago*	Comparing the response of Taylor and Commonwealth glacier to meteorological drivers using a 22-year surface energy balance record
16:15	Ruby Muir* *Victoria University of Wellington*	Late glacial climate evolution in the Patagonian Andes (44-47° S) from glacier modelling
16:30	Heather Purdie *University of Canterbury*	Rolleston Glacier mass balance: trends and methods of observation
16:45	Jim Salinger *Victoria University of Wellington*	EOSS & Ice Volume Heatwaves
17:00-onwards	**Evening activities and dinner:** Gondola and Coronet Bar are open until 20:00 Vegetarian chili and nachos will be available at **Joel Lodge** from 19:00 (no formal dinner time)	

* student presentation

Friday, February 10, 2023		
7:00-9:00	Breakfast available at **Joel Lodge**	
9:30-10:15	**Session 3: Antarctic glaciology**	
9:30	Dave Prior *University of Otago*	Structural Glaciology of the Priestley Glacier shear margin.
9:45	Martin Forbes* *University of Otago*	PGO: fits Pretty Good with ice shelf rift Observations
10:00	Rodrigo Gomez-Fell* *University of Canterbury*	Ice tongues of the Western Ross Sea
10:15-10:45	Break	
10:45-11:45	**Session 4: Cryosphere mapping, hazards and process**	
10:45	Aubrey Miller *University of Otago*	Insights into the July 2022 storm in Aoraki Mount Cook National Park
11:00	Ellorine Carle* *University of Otago*	Watching rocks fall (slowly) with DEMs and computer vision
11:15	Marek Ewertowski *Adam Mickiewicz University/ University of Canterbury*	Impact of landslides on glacier dynamics – project outline
11:30	Eva Nielsen* *University of Canterbury*	Can we trust the assumption of homogenous land cover in remotely sensed land and ice surface temperature?
11:45-13:00	Lunch break: Make your own sandwiches back at **Joel Lodge**	
13:00-13:30	**Nigel Kerr: Ski Area Manager, Coronet Peak**	
13:30-14:30	**Session 5: Ice shelf - sea ice - ocean interaction**	
13:30	Jed Thompson-Fawcett* *University of Otago*	Comparing simultaneous measurements taken from two CTD instruments in supercooled water
13:45	Zach Roberts* *University of Otago*	Flow in the HiPSMI system: investigating its effect on salinity and temperature measurements
14:00	Nina Caldarella* *University of Otago*	Using an acoustic profiler, a camera and plume models to research frazil ice
14:15	Andrew Pauling *University of Otago*	Upcoming research into climate impacts from Antarctic ice-mass loss in a multi-model experiment

14:30-15:15	Break	
15:15-16:30	**Session 6: Sea ice isotopes and interannual variability**	
15:15	Maia Gasson* *University of Otago*	Isotope Fractionation in Modelling Sea Ice Growth Rates
15:30	Briana Cate* *University of Otago*	Investigating the effect of partial dissolution on the transport of chemicals in sea ice
15:45	Greg Leonard *University of Otago*	The winter 2019 sea-ice conditions in McMurdo Sound, Antarctica – an anomaly or something more?
16:00	Inga Smith *University of Otago*	Sea ice in McMurdo Sound in 2022 was dramatically thinner than usual: what happened?
16:15	Maren Richter* *University of Otago*	Drivers of interannual fast-ice thickness variability on McMurdo Sound
16:30 - onwards	**Evening activities and dinner:** Student awards ceremony at **Joel Lodge** at 19:00, followed by dinner (pasta with tomato or Bolognese sauce)	

Saturday, February 11, 2023	
9:30- 14:00	Field trip: Departure from Joel Lodge at 9:30 am. Please remember to make and pack your own lunches before departing.

* student presentation

Abstracts

A snowy Hooker Valley, Aoraki Mount Cook National Park, winter 2022. Photo credit: Aubrey Miller

A snowy Hooker Valley, Aoraki Mount Cook National Park, winter 2022. Photo credit: Aubrey Miller

Using an acoustic profiler, a camera and plume models to research frazil ice

Nina Caldarella[1], Gregory H. Leonard [2], Inga J. Smith [1], Lars H. Smedsrud[3], Max Thomas[1], Eamon Frazer [1]

[1]University of Otago, Department of Physics
[2]University of Otago, School of Surveying
[3]University of Bergen, Geophysical Institute, Norway

Frazil ice nucleates in supercooled water underneath ice shelves (named: ice shelf water). Less is known about what is underneath ice shelves than there is about the surface of the moon, while this zone and its inhabitants may be very vulnerable to changes in ocean temperature and circulation due to global warming. Earlier and on-going research offers a range of models for frazil-laden ice shelf water. Only recently have direct observations indicated the presence- and effects of frazil-laden ice shelf water in McMurdo Sound. Additionally, recent efforts on the development of an acoustic water column profiler (named: AZFP) with the purpose of retrieving parameters of a frazil ice crystal size distribution have resulted in data that can be used with the earlier models for frazil-laden ice shelf water. Validating and constraining the models using AZFP retrievals is in progress. This will quantify ice shelf water parameters more accurately and help to better understand the significance of including frazil ice in larger scale models. This is a logical and necessary step to predict the future state of frazil ice and super cooled water on a warming planet. In this talk the first results from the measurements from the 2022 field season in McMurdo Sound will be presented and evaluated with tide model outputs and previous modelling studies.

Watching rocks fall (slowly) with DEMs and computer vision

Ellorine Carle[1], Pascal Sirguey[1]
[1]National School of Surveying, University of Otago

Fox Glacier/Te Moeka o Tuawe has retreated rapidly since 2008 leading to substantial erosion and instability on adjacent hillslopes. While properties of the glacier itself are relatively well-studied, the dynamics of surrounding paraglacial hillslopes are lesser known. Five high resolution digital elevation models (DEMs) captured yearly between 2017 and 2021 are used to investigate the recent evolution of hillslopes near the icefall and glacier terminus. Using a novel feature tracking methodology, an optical flow algorithm is applied to multiple DEM-derived hillshade pairs to resolve dense grids of 3-D surface displacements over the area. The technique enables rapid identification of multiple slow-moving landslides in the area, quantification of erosion/deposition volumes, and characterisation of translational movements for each year and the overall six-year period.

Investigating the effect of partial dissolution on the transport of chemicals in sea ice

Briana Cate[1], Max Thomas[1], Jack Garnett[2], Inga J. Smith[1], and Martin Vancoppenolle[3]
[1]Department of Physics, University of Otago
[2]Lancaster Environment Centre, Lancaster University, Lancaster, LA1 4YQ, U.K.
[3]Sorbonne Université, Laboratoire d'Océanographie et du Climat (LOCEAN), Institut Pierre-Simon-Laplace (IPSL), CNRS/IRD/MNHN, Paris, France

We investigate the effect of partial dissolution on the transport of chemicals in sea ice. Physically plausible mechanisms are added to a brine convection model that decouple tracers from convecting brine. The model is evaluated against a recent observational dataset where a suite of qualitatively similar chemicals (perfluoroalkyl substances, PFAS) with quantitatively different physico-chemical properties (carbon chain lengths from 4 to 12, partitioning coefficients ranging over several orders of magnitude) were frozen into growing sea ice. When the chemicals are modelled as perfectly dissolved they behave identically to the bulk salinity, the model performs poorly and does not reproduce the concentration of high chain length PFAS. A simple decoupling scheme where PFAS are decoupled from salinity by partitioning to a stationary phase as a constant fraction gives better performance. A scheme where the decoupling is proportional to the brine salinity performs similarly well. A scheme where the decoupling is proportional to the internal sea-ice surface area performs poorly. All decoupling schemes capture an observed general enrichment of longer chained PFAS, and can produce concentrations in the uppermost sea-ice layers above that of the underlying water concentration, as observed.

Improving the representation of seasonal snow hydrology within the New Zealand Water Model

Jono Conway[1]
[1]NIWA, Lauder

Snow models are useful tools for integrating the effects of snow processes into hydrological forecasts. This presentation will cover recent efforts to improve the representation of snow processes within Topnet, the surface water model used within the New Zealand Water Model for a range of applications including national water accounting, policy development, environmental limit setting, and operational forecasting (e.g. Aotearoa Flood Awareness System). A new snow model parameter set is derived to mimic melt rates and climate sensitivity of surface energy balance model simulations. Current and new parameter sets are validated against point snow observations using in-situ AWS as driving data. Distributed simulations driven with various meteorological data are validated against MODIS observations, with a focus on seasonal variations in snow covered area. The impact of different parameter sets on the seasonal variation of simulated streamflow is shown, and future developments are discussed.

Impact of landslides on glacier dynamics – project outline

Marek W. Ewertowski[1,2], Gisela Domej[1], Jakub Małecki[1], James Shulmeister[2], Aleksandra M. Tomczyk[1]
[1]1Faculty of Geographical and Geological Sciences, Adam Mickiewicz University, Poznań, Poland
[2] School of Earth and Environment, University of Canterbury, Christchurch, New Zealand

Glaciers are commonly used as indicators of climate changes, with worldwide glacier retreat being one of the most iconic images of the effects of a warming climate. However, glaciers respond not only to changes in climate but also to other (e.g., tectonic activity, landslides) changes in local environment. For example, large landslides can affect the dynamics of glaciers by several different processes, including limitation of ablation, change of driving stress, or increase in meltwater production. Our project will focus on glacier-landslide interactions and associated hazards by studying these topics on several spatial scales (global, catchment, landform). This presentation will show the background and general ideas of the research and approaches we plan to use. An inventory of landslides which occurred on glacier surface will be prepared on a global spatial scale based on the literature review and supplemented using medium resolution (10-50 m) satellite imagery (Landsat, Sentinel, Aster). General characteristics and dynamics of glaciers and landslides in the catchment scale will be mapped and quantified for several benchmark glaciers affected by large landslides. Mapping in this scale will be based on time series of high-resolution satellite imagery (0.3-1 m) and available high-resolution DEMs. Landslide characteristics will be investigated on a detailed spatial scale based on UAV data (0.05-0.10 m resolution) and field mapping.

Marek Ewertowski's visit to the School of Earth and Environment, University of Canterbury, was funded by the Polish National Agency for Academic Exchange NAWA within the framework of the Bekker Scholarship Programme (decision number BPN/BEK/2021/2/00017/DEC/1).

Seasonal Snow, Volcanic Super Eruptions and Electricity Crises

Blair Fitzharris[1]
[1]School of Geography, University of Otago

This links the three elements of seasonal snow storage, the Pinatubo super volcanic eruption of June 1991 (VEI = 6), and a major New Zealand electricity crisis. Can such an event of thirty years ago happen again? I attempt a retrospective analysis as to what happened, as based on my involvement. The Pinatubo eruption in the Philippines now appears to have had the biggest impact of any for much of the 20th Century. Could such an event happen again, despite an obvious warming world? I describe my experience stemming from a coincidental visit to the Philippines, a retrospective reflection on a career in snow science and the urgent reaction of Government to a lack of electricity in the winter of 1992. This led to the development of SnowSim, now widely used in the electricity pricing market. It was a first attempt to model seasonal snow storage in the hydro catchments of New Zealand. SnowSim continues to provide real time information to electricity companies so as to better manage their water storage and generation.

PGO: fits Pretty Good with ice shelf rift Observations

Martin Forbes[1], Christina Hulbe[1]
[1] School of Surveying, University of Otago, Dunedin, New Zealand

Laterally propagating, through-cutting rifts govern the iceberg calving component of Antarctic ice-shelf mass balance and determine the geometry of the seaward fronts of these floating ice masses. Despite their importance, physical limits on rift propagation are not well understood, there have been few forward-modelling studies of rift behaviour and there are no accessible modelling frameworks with which to meet these challenges. The present work describes and justifies a novel numerical approach that applies linear elastic fracture mechanics (LEFM) to simulate antarctic ice-shelf rifts, addressing this gap.

Rifts propagate in response to the total stress tensor in the neighbourhood of their tips. By splitting the floating ice, rifts create internal boundaries on which both glaciostatic and hydrostatic overburden act, however they are imbalanced, leading to a net internal force (which we call the GHI). Here, a novel set of numerical tools are used to investigate rift propagation with specific attention to conditions on the internal boundary. Application to a rift in the central Ross Ice Shelf shows that the offset between ice shelf principal stresses (PS) and the GHI (which we call the PGO) prediction regions in which rifts are active. Because it depends mainly on shelf thickness and rift orientation, PGO can be mapped for all floating ice shelves.

Isotope Fractionation in Modelling Sea Ice Growth Rates

Maia Gasson[1], Briana Cate[1], Inga Smith[1], Max Thomas[1]
[1] Department of Physics, University of Otago, Dunedin, New Zealand

As sea ice forms the proportion of $^{18}O/^{16}O$ and $^{2}H/^{1}H$ in the ice increases relative to the seawater from which it forms – the heavier isotopologues are preferentially entrapped. The degree of fractionation is dependent on various environmental conditions as the ice forms, notably the isotopic composition of the seawater and the rate of freezing during the sea ice formation. This dependence means that, theoretically, the growth history of sea ice could be inferred from the $\delta^{18}O$ values of an ice core extracted at the end of the growing season. An accurate model of sea ice fractionation would allow information regarding how much ice shelf melt and salt flux was occurring through the prior growth season to be deduced with less of a need for instruments to be left through the season. We are in the early stages of developing such a model. Here, we present a model that takes sea ice thickness with time and the temperature of the ice at even depth intervals through time as input and produces an expected $\delta^{18}O$ vertical profile for the ice core. A review of the sea ice fractionation literature identified a range of experiments, from both field and laboratory conditions, that collected appropriate data sets. These data sets were then extracted and worked into a form appropriate for input into the model, primarily through interpolation. To check the accuracy of the model, the $\delta^{18}O$ profiles produced from these input datasets will be compared to those measured.

Ice tongues of the Western Ross Sea

Rodrigo Gomez-Fell[1], Wolfgang Rack[1], Heather Purdie[1], Oliver Marsh[2], Christian Wild[3]
[1]Gateway Antarctica, School of Earth and Environment, University of Canterbury, Christchurch, New Zealand.
[2]British Antarctic Survey, Cambridge, UK
[3]College of Earth, Ocean, and Atmospheric Sciences, Oregon State University, Corvallis, OR, USA

Antarctica has been losing mass at an accelerating rate, with most of its ice being lost through the ice shelves and ice tongues at the fringes of the Antarctic continent. Basal melt and calving of the floating portions of the ice sheet are the main mechanisms of ice loss. Here we focus on one of the stable regions of Antarctica, the Western Ross Sea, looking into the stability mechanisms of ice tongues. Using remote sensing tools, we look into the prevalence of ice tongues in the Western Ross Sea. First by an ice tongue collapse observation, second by the basal mass balance of 12 ice tongues in the sector, and third by detecting lateral flexure due to ocean forcing. From three different studies, we concluded that fast ice persistence enhances ice tongue growth, delays ice tongue calving and acts as a protective mantle against ocean erosion and tidal forcing. Due to the unconfined nature of Ice tongues, they are vulnerable to different oceanic processes. Therefore, we ask what will be the fate of such magnificent features with future changes in fast ice cover?

Comparing the response of Taylor and Commonwealth glacier to meteorological drivers using a 22-year surface energy balance record

M. G. Hofsteenge[1], N. Cullen [1,] J. Conway[2] ,M. Katurji[3], C.H. Reijmer[4], M. van den Broeke[4]
[1] School of Geography, University of Otago, Dunedin, New Zealand
[2] National Institute of Water and Atmospheric Research, Lauder, New Zealand
[3] School of Earth and Environment, University of Canterbury, Christchurch, New Zealand
[4] Institute for Marine and Atmospheric research Utrecht, Utrecht University, Utrecht, the Netherlands

In the McMurdo Dry Valleys (MDV) of Antarctica thrives a unique ecosystem under extreme cold and dry conditions. The limited snowfall that falls on the valley floor quickly sublimates and therefore glacial melt is the most important input to the streams and ice-covered lakes that provide water for the ecosystem. Understanding what drives the variability and changes in glacial meltwater is therefore of great importance to foresee ecosystem changes in a warming world. To assess the temporal variability and meteorological drivers of glacial melt in Taylor Valley, a 22-year surface energy balance (SEB) record is constructed for Taylor and Commonwealth glacier. Automatic weather station observations in the ablation area of each glacier from the Long-term Ecological Research (LTER) Program are gap filled and completed using locally-tuned parameterisations. The two SEB records are compared to understand the different response of two nearby glaciers (~30 km apart) to local and regional climate forcing. The more melt dominated Commonwealth glacier shows strong seasonal variability in ablation. The closer proximity of Commonwealth glacier to the ocean leads to more rapid changes in albedo as controlled by summer snowfall events. Not only does the presence of snow but the larger variability in ice albedo compared to Taylor glacier explains much of the seasonal variability in melt. Another major driver is the number of degree days above freezing for both glaciers, which is strongly linked to foehn wind events in Taylor Valley. The further inland Taylor Glacier experiences drier and windier conditions and therefore sublimation dominates ablation and melt occurrence. Cloud cover and snowfall in summer switch off glacial melt in summer on both glaciers. We have also used ERA5 fields to study the moisture sources of the MDV precipitation and clouds. This will help us understand how changes in moisture and regional circulation patterns might impact the MDV glaciers and ecosystem in a warming climate.

The winter 2019 sea-ice conditions in McMurdo Sound, Antarctica – an anomaly or something more?

Greg Leonard[1], Kate Turner[2,3], Maren Richter[2], Maddy Whittaker[2], Inga Smith[2]
[1]National School of Surveying, University of Otago, Dunedin
[2]Department of Physics, University of Otago, Dunedin
[3]National Institute of Water and Atmospheric Research, Wellington

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McMurdo Sound sea ice can generally be partitioned into two regimes: (1) a stable fast-ice cover, forming south of approximately 77.6 ∘S around March – April and then breaking out the following January – February, and (2) a more dynamic region north of 77.6 ∘S that the McMurdo Sound and Ross Sea polynyas regularly impact. In 2019, a stable fast-ice cover formed unusually late due to repeated break-out events. Here we analyse the 2019 sea-ice conditions and relate them to a modified storm index (MSI), a proxy for southerly wind events. We find there is a strong correlation between the timing of break-out events and several unusually large MSI events. There is some evidence that a stable sea-ice cover may be forming later in the season in recent years, suggesting that the fate of the fast-ice cover may be a symptom of some larger change. Addressing this question is a focus of current research efforts in the Sea Ice Research Group at the University of Otago.

Insights into the July 2022 storm in Aoraki Mount Cook National Park

Aubrey D. Miller[1]**,** Todd A. N. Redpath[1,2], Pascal Sirguey[1], Simon C. Cox[3], Perry Bartelt[4,5], Don Bogie[6], Jono P. Conway[7], Nicolas J. Cullen[2], and Yves Bühler[4,5]
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[2]School of Geography, University of Otago, Dunedin, New Zealand
[3] GNS Science, Dunedin New Zealand
[4] WSL Institute for Snow and Avalanche Research SLF, Davos, Switzerland
[5] Climate Change, Extremes and Natural Hazards in Alpine Regions Research Center CERC, Davos Dorf, Switzerland
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A series of storms in June and early July 2022 resulted in an above-average snowpack in the central Southern Alps of New Zealand. A record-breaking winter storm in mid-July then brought 550 mm of precipitation with rain to high elevations. A series of alpine mass movements occurred during the storm, including a widespread snow avalanche cycle, debris flows, and erosion from rain runoff. We detail the sequence of events in the Kitchener avalanche path. Here, two large snow avalanches were followed by a relatively small debris flow. Substantial erosion of avalanche and debris flow deposition, as well as the underlying alluvial fan, were induced by runoff from over 300 mm of rain falling after the first avalanche. The Kitchener path saw the largest avalanche in over 40 years, testing the utility of a diversion berm constructed for a 1:100-year event. Results from a UAV lidar survey after the event, along with numerical modelling of the snow avalanches help characterize the hazard sequence. The rain-on-snow event occurred on an above-average winter snowpack, which offers insights into future hazards posed by increasingly frequent extreme alpine precipitation.

Figure 1: Kitchener avalanche path after July 18-19 event. Image Credit: Department of Conservation

Figure 2Figure 3: Kitchener avalanche path after July 18-19 event. Image Credit: Department of Conservation

Late glacial climate evolution in the Patagonian Andes (44-47° S) from glacier modelling

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Numerical glacier models applied to moraine chronologies provide an opportunity to quantify past climate change. Here we apply a two-dimensional coupled mass balance – ice flow model to well-dated moraine sequences of two Patagonian glaciers at 44 and 47°S to reconstruct the local temperatures during both the Antarctic Cold Reversal (14.7–13 ka) and the Younger Dryas (12.9–11 ka). Modelled temperature anomalies during the Antarctic Cold Reversal are 2.6 ± 0.4 °C at 44°S, and 2.9 ± 0.6 °C at 47°S. At both locations this cold event is followed by temperature increases of +0.6 – 0.7 °C or precipitation reductions of c. 20% to drive glacier retreat to moraines deposited during Younger Dryas time. The consistent climatic anomalies between these two latitudes suggest this region of Patagonia was responding to a common climatic event. Further, the late-glacial temperature anomalies found here compare well to those determined by similar glacier modelling techniques in New Zealand, at 43–44° S. These results support a trans-Pacific response throughout the southern mid to high latitudes (43–47° S) during the ACR that is best explained by a northward expansion of the south westerly winds.

Can we trust the assumption of homogenous land cover in remotely sensed land and ice surface temperature?

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Extreme warming events in the McMurdo Dry valleys, Antarctica, are often associated with foehn induced warming. These events c**an cause** the near surface air temperature to rise above freezing and are furthermore linked to anomalous **seasonal** melt **events**. The remotely sensed Land and Ice Surface temperature (LST, IST) products from the MODerate-resolution Imaging Spectroradiometer (MODIS) have proven capable of capturing the spatial a**nd temporal** extent of these warming events. However, the LST and IST product assumes a homogenous land cover type within the 1km^2 pixel and large errors has in previous studies been observed in areas with heterogenous surface types. In order to investigate temperature thresholds in the MODIS LST or IST products for melt occurrence, it is important to understand any bias related to these sub pixel variations. To assess this bias a remote sensing observational campaign was carried out in the Austral summer of 2022-2023 in the McMurdo Dry valleys and Terra Nova Bay regions. A helicopter-mounted thermal infrared and visible camera system was developed for measuring the skin temperature of various surface types for a temperature based validation of the MODIS LST and IST. A better understanding of the MODIS LST and IST in these different environments, provides confidence to identify extreme warming events in the 23 years of MODIS record throughout the Antarctic coastline.

Upcoming research into climate impacts from Antarctic ice-mass loss in a multi-model experiment

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Antarctic ice-mass loss from ice sheets and ice shelves is increasing and is projected to increase further as the climate warms. The fresh water entering the Southern Ocean due to this ice-mass loss has been proposed as a mechanism responsible for the lack of decline in Antarctic sea ice area, in contrast to the loss seen in the Arctic. Though this increased Antarctic ice-mass loss is expected to impact climate it is absent from almost all models in the current Coupled Model Intercomparison Project (CMIP6) and the New Zealand Earth System Model (NZESM). Further, previous non-CMIP6 model experiments that include changing Antarctic ice-mass loss suggest that the climate response depends on the model used, and the reasons for this model dependence are not clear. Taken together, the absence of a key process from the CMIP6 ensemble and the discrepancies between models that include this process hamper New Zealand's ability to anticipate climate change and our understanding of this important piece of the climate system.

We will use the physical core of the NZESM, HadGEM3-GC3.1, to contribute model experiments to the Southern Ocean Freshwater release model experiments Initiative (SOFIA), an international model intercomparison, in which freshwater is added to the ocean surrounding Antarctica to simulate the otherwise missing ice-sheet mass loss. This unique suite of models will allow us to evaluate HadGEM3-GC3.1 against several other climate models, identify reasons for model discrepancies, and quantify the potential impact of the absence of increasing Antarctic ice-mass loss on climate modelling for New Zealand.

Modifying a snowpack model to simulate glacial melt processes in the McMurdo Dry Valleys

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Glacial melt is the primary source of freshwater for the fragile microbial ecosystem in the McMurdo Dry Valleys (MDV) of Antarctica. These glaciers are cold-based, with internal temperatures around -18°C, however, air temperatures hover around 0°C for several weeks in the summer and föhn wind events can rapidly raise ice surface temperatures to the melting point. Thus, episodical glacial melt is sensitive to small changes in the climate.

The aim of this research is to adapt a detailed snowpack model embedded in a distributed hydrological model to simulate the surface energy balance and run-off of a glacier in the MDV. To do this, the Crocus snowpack model in the WRF-Hydro-Glacier modelling scheme, which has been used for avalanche forecasting and applied to temperate glaciers, is adapted to the MDV. Several modifications are made to model calculations and parameters to allow the model to successfully simulate surface energy balance and runoff in this environment. For example, the parameters for the Crocus albedo scheme are adjusted to obtain band profiles for snow, firn and ice that replicate observed albedo and remain internally consistent between surface types. The modelling system is then validated against data from an automatic weather station, eddy covariance measurements and stream discharge. It is shown to be suitable for future efforts to model the full hydrological cycle of glacial meltwater in this region.

Structural Glaciology of the Priestley Glacier shear margin

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The Priestley Glacier feeds the Nansen Ice Shelf in Terra Nova Bay, Antarctica. In 2018-19 and 2019-20 we completed surveying, geophysical investigations and ice coring in the lateral, true-left margin of the glacier, a few km downstream of the grounding line. In November 2022 we had blue-ice conditions (no snow cover: for six days) allowing us to see and measure the structures in the ice. Structures include ice layers (a), melt veins (a,d) and cracks/fractures, with folds (b,c) and shear zones (c) modifying the layers and melt veins.

A structural synthesis was made along a line of marker stakes (from Dec 2019) across the glacier, using video from a GoPro camera, looking at the ice from the top of a 5m pole. Broader context came from a helicopter overflight. Locally, detailed measurements were made. We will show how the structures relate to the shear margin velocity field as constrained by motion of marker stakes from repeat GNSS measurements.

Purdie et al. (a)

Influence of crevasses on air temperature over a maritime glacier

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In mountain regions around the world, crevasses in glacier accumulation areas undergo cycles of burial and re-exposure between melt seasons. Climate warming is extending the length of the ablation season, meaning that crevasses are exposed at the glacier surface for longer. Analysis of air temperature inside crevasses in the accumulation area of a maritime glacier found that in summer, air temperature is frequently positive and can at times exceed surface air temperature, with greatest warming in wide crevasses orientated favourably for maximum solar radiation retrieval (Purdie et al. 2022). Here we extend this research by 1. Analysing thermal imagery to explore the spatial extent over which in-crevasse warming influences the wider glacier area. Preliminary results of this thermal analysis show that the 'skin' temperature of crevassed regions is often 2°C warmer than the surrounding snow surfaces, and that crevasses retain heat throughout the night. 2. Using in-crevasse vertical (u-wind) and temperature data, we examine whether crevasses can at times become heat sources. However, at this stage results are still inconclusive. While in one crevasse we observe vertical flow coincident with times when the crevasse is warm at depth, other times the signal is mixed and frequently the u-winds at 1 and 4 m depths seem disconnected. Improvement to the in-crevasse anemometer mounting is required to increase sensor stability and data acquisition, and more consideration needs to be given to crevasse morphology, which appears also appears to influence in-crevasse airflow.

Purdie et al. (b)

Rolleston Glacier mass balance: trends and methods of observation

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Rolleston Glacier is a small cirque glacier (0.1 km^2) located at relatively low elevation (1710-1900 m asl) in Arthurs Pass National Park. It is one of only two New Zealand glaciers at which mass balance is directly measured. Over the past 12 years the average annual mass balance determined by the field programme is -0.7 m w.e., with a cumulative mass loss of -8 m w.e. The variability in the summer balance is almost twice that of the winter balance, indicating that summer balance drives year-to-year variability. In March 2021 and 2022 a LiDAR survey was flown over the glacier from which the average surface elevation difference was estimated to be -1.01 ± .05 m. Using the mapped end-of-summer snowlines from 2021 and 2022, we subdivide the glacier into accumulation (550 kg m^{-3}), firn (800 kg m^{-3}) and ablation (917 kg m^{-3}) zones, to enable conversion of the DEM height difference (m) into m w.e. The mass a balance estimates for the 2021/22 season were -0.87 and -1.07 m w.e. for the LiDAR and glaciological methods respectively. These data will also be compared to a net balance derived from DEM's generated from Structure from Motion (SfM) analysis using photographs taken during the NIWA end-of-summer snowline flight

Satellite observations of snow depth to support hydrological modelling in Aotearoa New Zealand

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Modern satellite photogrammetric mapping offers a step-change in mapping snow depth in a spatially continuous manner across relatively large areas, with high spatial and flexible temporal resolution. This research aims to leverage SPM to map snow depth through the central Southern Alps through the winter and spring of 2012, providing improved empirical characterisations of seasonal snow and supporting the development of a redistribution model. Together, these efforts are anticipated to enhance the representation of seasonal snow within NZWaM/TopNet. Targeting peak accumulation and early melt for the 2012 winter season, SPM yields snow depth maps across the Jollie Catchment a spatial resolution of two metres. Clear detection of the snowline highlights the performance of SPM in terms of signal-to-noise. Evidence of snow redistribution is widespread, with the role of avalanching particularly apparent in shifting substantial volumes of snow down-slope. Snow depth maps allow the total basin snow water equivalent (SWE) storage to be estimated, but this estimate is sensitive to the choice of density function. Hypsometric analysis, which facilitates comparisons with NZWaM/TopNet reveals that maximal snow depths occur at mid-elevations within the Jollie Catchment, which translates to the bulk of SWE storage (75%) residing in the elevation range of 1700 – 2300 m around the time of peak accumulation. While modelled (TopNet) and measured (SPM) hypsometric distributions are similar, preliminary analysis suggests that TopNet substantially underestimates total SWE around the time of peak accumulation. SPM represents a powerful tool for understanding seasonal snow in Aotearoa New Zealand, while also highlighting uncertainties around snow density and the input data typically used for snow modelling.

Flow in the HiPSMI system: investigating its effect on salinity and temperature measurements

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The measurement of supercooled seawater in the Antarctic region is a key part of our understanding of sea ice in the Southern Ocean, but it is a feat that does not come without significant technical challenges in determining salinity and temperature. The "High Precision Supercooling Measurement System" (HiPSMI) is a novel device that seeks to overcome these challenges through a setup involving two sets of conductivity and temperature (CT) sensors, separated by a "Frazil Melting Unit" to melt any entrained frazil ice. Unfortunately, due to viscous effects of the seawater, parcels leaving the first CT array are likely to become significantly distorted as they travel to the second CT array. This project aims to investigate and quantify the extent of this distortion, and how this distortion affects the measurement at the second set of sensors. Understanding and quantifying this latter effect will allow us to validate the data acquired by HiPSMI, enabling the instrument to be used in the field with high confidence in the spatial and temporal resolution of the measurements.

Drivers of interannual fast-ice thickness variability on McMurdo Sound

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The fast-ice cover in McMurdo Sound has been remarkably stable since the earliest records more than 100 years ago. This is likely due to supercooled water flowing out from under the McMurdo Ice Shelf, which allows the sea ice to grow through heat loss to the ocean, as well as to the atmosphere. We will present a fast-ice thickness dataset covering 1986--2020 which we will connect to atmospheric and ocean drivers on monthly and seasonal scales in order to provide a baseline of the interannual variability in fast-ice thickness. We thus provide one of the longest studies of drivers of interannual fast-ice thickness variability from high-quality, in situ observations. Our work highlights the drivers most likely to influence fast-ice thickness in McMurdo Sound. Thicker fast ice is related to lower temperatures, higher average off-shore winds and lower offshore storminess. The strongest connections were found between thickness and freezing degree days, as well as autumn to winter storminess. Future extreme events and long-term trends can be assessed against the baseline presented here, helping us better understand the balance between ice, ocean, and atmosphere. Further, this provides information on gaps in our understanding of regional fast-ice processes, and will hopefully contribute to possible future work towards a model with regional predictive capability of fast-ice in McMurdo Sound.

EOSS & Ice Volume Heatwaves

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During austral warm seasons (NDJFM) of 1934/35, 2017/18, 2018/19 and 28 2021/22 the New Zealand (NZ) region experienced the most intense coupled ocean/ atmosphere (MHW/AHW) heatwaves on record. Average temperature anomalies over land and sea were +1.2 to 1.4°C above average. The end of summer snowline (EOSS) time series (Salinger et al 2021) was used to estimate Southern Alps glacier mass balance from 1977 to 2022 for EOSSAlps (Salinger et al 2023). Regression relationships were employed to calculate EOSSAlps for 1935 and 2022, using Hermitage Mt Cook glacier season annual mean temperature, the SAM index, and Kidson Trough and Block regimes frequencies (Salinger et al (2023). The methods described in Salinger et al (2021) were used to estimate downwasting and proglacial lake growth. Ice volume loss in the Southern Alps for the small and medium glaciers was estimated to be 0.4 km^3 volume in 1934/35, 2.1 km^3 in 2017/18, 2.0 km^3 in 2018/19 and 1.7 km^3 for 2021/22.This totals 5.9 km^3 for the three recent heatwave warm seasons, 22% of the total ice volume of the Southern Alps in the 1977 inventory (Chinn 2001). For the three recent heatwave summers, total losses from all glaciers amounted to 9.3 km^3, 17% of the 1977 total. The 2018 – 2022 period represents the largest ice loss in any 5-year period since 1949 (Salinger, et al. 2021).

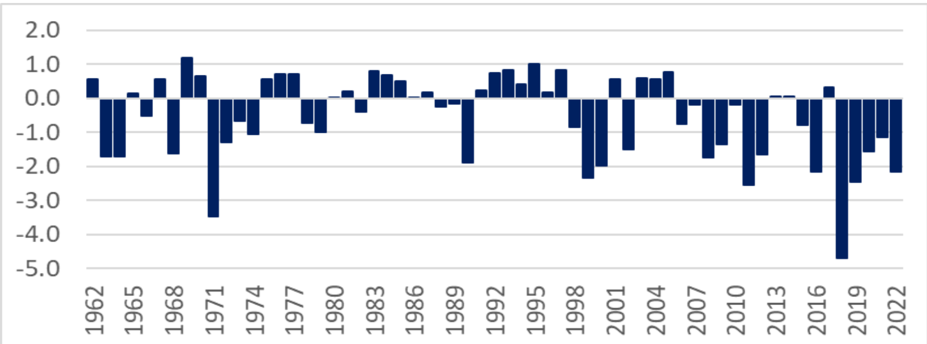

Figure 4: Southern Alps ice volume. a. Southern Alps ice volume change (km3 of water equivalent), between years, for all glaciers of the Southern Alps from 1962 to 2022.

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Figure 5: Southern Alps ice volume. a. Southern Alps ice volume change (km3 of water equivalent), between years, for all glaciers of the Southern Alps from 1962 to 2022.

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Sea ice in McMurdo Sound in 2022 was dramatically thinner than usual: what happened?

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In October 2022, Antarctic sea ice was only around 1 m to 1.3 m thick in some McMurdo Sound locations where sea ice would normally be about 2 metres thick by October. This posed logistical challenges for the New Zealand Antarctic Programme and the United States Antarctic Program. For example, the University of Otago sea-ice measurement station, which is usually installed each winter by Scott Base staff driving onto the sea ice, had its 2022 installation delayed and in the end needed to be installed on foot because of issues with vehicle access onto the sea ice. The sea ice had broken out in the eastern part of McMurdo Sound as usual from late-January to late-February, 2022. This was predominantly first year sea ice, although some multi-year ice also broke out. Sea ice then started to form again as usual in March 2022. From late-May onwards, every one to two weeks a series of strong south-westerly wind events (over 50 kilometres per hour) occurred. Those winds kept blowing out newly-formed sea ice for most of the eastern sound except for a stable crescent of sea ice immediately between Scott Base and the McMurdo Ice Shelf. In some locations where sea ice did stay put, the snow was thicker than usual, reducing the rate of thermodynamic thickening. Why did this series of events happen, and will they happen again? It is not yet clear if this is climate change related, so more research is needed.

Comparing simultaneous measurements taken from two CTD instruments in supercooled water

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When collecting oceanographic measurements in areas such as McMurdo Sound, Antarctica, high precision and accuracy measurements are required to observe a phenomenon known as supercooling (when a substance is at a temperature below its freezing point yet in a liquid state). These high precision and accuracy measurements are required as seawater is often supercooled by only a few millikelvin, a minor difference in temperature. Here we compare simultaneous measurements taken from two common, commercially available CTD (conductivity, temperature, and depth) instruments (SeaBird 19plus V2 and RBR concerto 3) on the same water column. This is important for sea ice growth processes understanding, as supercooled seawater can help detect platelet ice formation and basal melt in ice shelves, for example.