SIRG 2024 ANNUAL WORKSHOP

Programme and abstracts

February 14 – 16 2024,
NIWA Lauder Atmospheric Research Station, New Zealand

Antarctica New Zealand

NIWA Taihoro Nukurangi

WELCOME

Kia ora and welcome to the SIRG 2024 Annual Workshop.

We’re excited to host you all in sunny Central Otago this year. We’ve got a great line up of presentations to enjoy as well as a field trip to highlight some of the science and industry that relies on this unique natural environment.

Central Otago is the driest place in New Zealand, the furthest from the coastline, and holds the records for coldest winter temperature. While summer in Central is the antithesis of all things frozen, snow plays a vital role in the hydrology of the region. Snow on the large fault-block mountains surrounding Lauder plays a vital role in storing water that melts into rivers and aquifers later in spring and summer – providing water for instream habitat, stock water and irrigation when temperatures rise. Many ranges see snow cover lasting over 6 months and snow drifts tens of metres thick that survive right through the hot summer!

We hope you enjoy the conference and the local hospitality.

Ka kite anō au i a koutou

SIRG 2024 organising team (Alice, Jono, Lawrence, Marte, Rasool, Stefan)

Nicolas Cullen working on the weather station at Brewster Glacier, New Zealand. Photo: Marte Hofsteenge

ACKNOWLEDGEMENTS

SIRG 2024 would not have been possible without the financial support of our sponsors: NIWA and Antarctica New Zealand.

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.

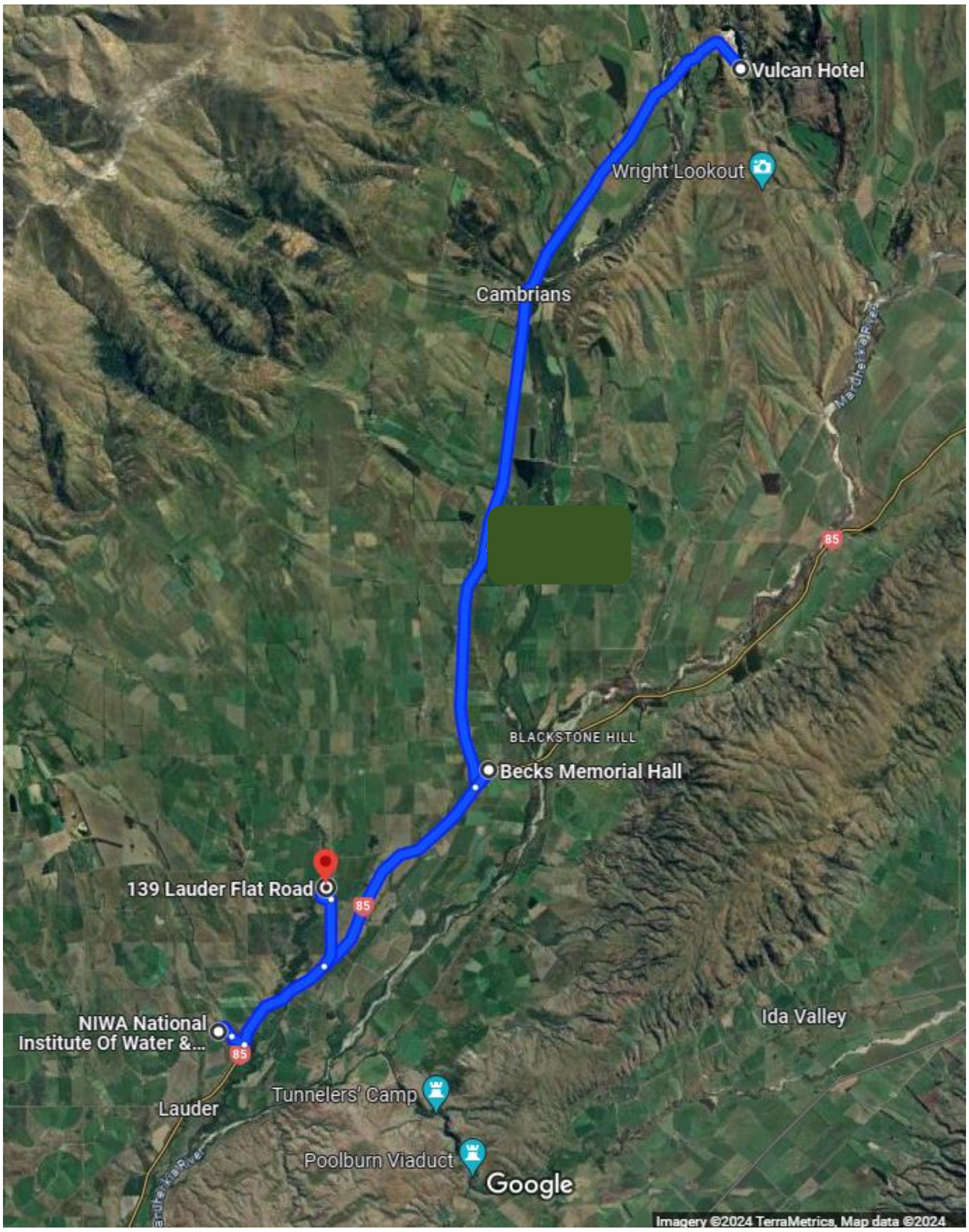
SIRG is the New Zealand branch of the International Glaciological Society: http://www.igsoc.org/ .

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

Land fast and nilas sea ice in the McMurdo Sound, Antarctica. Photo: Marte Hofsteenge

VENUE INFORMATION

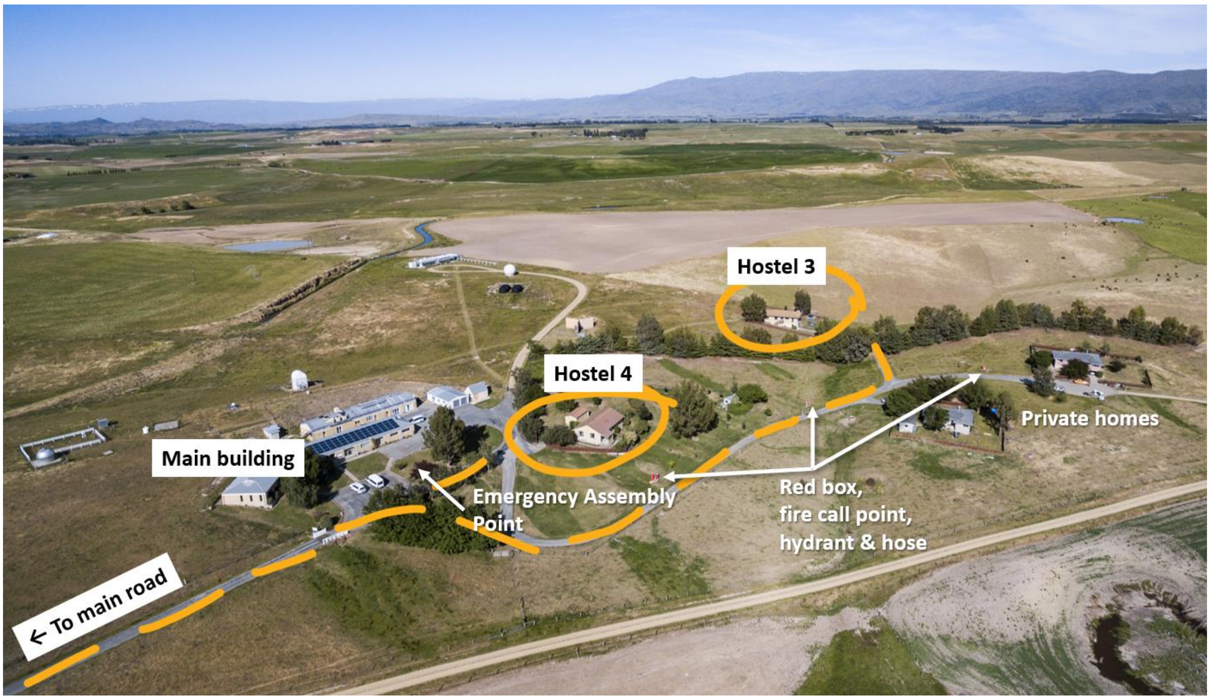
Workshop sessions will be held in the Becks Hall (7 min drive from NIWA Lauder) with accommodation at NIWA Lauder (houses + camping) and Becks Hall (camping). Wednesday night dinner is at 139 Lauder Flat Road, with Thursday dinner at Becks Hall, followed by a desert at the Vulcan Hotel in St Bathans (15 mins drive). The field trip will start at NIWA Lauder and finish at the Clyde Dam, Fruitgrowers Road, Clyde. The Programme gives more details on locations and timing.



Map of key locations for SIRG 2024

Becks Memorial Hall: 4253 Wedderburn-Becks Road, Becks 9377

NIWA Lauder: 3513 Becks-Lauder Road, Lauder 9377



Aerial view of NIWA Lauder indicating hostel and main building locations, with driveway access marked.

Accommodation

Accommodation as per registration form is listed below. We haven't allocated people to specific hostels or camping locations – just work it out considering:

- Hostel 4 – female only – 3 bedrooms with 2 beds or mattress in each bedroom
- Hostel 3 – mixed / male only rooms – 3 bedrooms with 2 beds or mattress in each bedroom
- Camping is encouraged at Becks Hall to spread out use of facilities – there are 2 showers at Becks Hall, 1 at each of the Lauder Hostels. But is some space to camp around each hostel.
- Lauder Hostels and Becks Hall have shower, toilet, and kitchen facilities incl. plates/cups/cutlery. **Bring your own bedding (sleeping bag/pillow), shower towel, soap, shampoo etc.**

Accommodation as per registration form:		
Hostels (bring your own bedding / shower towel)	**Camping (can use facilities in Becks Hall/houses)**	**Own accommodation**
Oliver Wigmore	Nicolas Cullen	Christian Zammit
Christina Hulbe	Pascal Sirguey	Jim Salinger
Madi Fleming	Anita Bentley	Blair Fitzharris
Ellorine Carle	Jessie Lindsay	Natalie Robinson
Heather Purdie	Todd Redpath	Jono Conway
Lijuan Wang	Marte Hofsteenge	Jacqui Stuart
Martin Forbes	Pablo Fuchs	Lawrence Kees
Tim Kerr	Julia Martin	
Ziyi Zhang	Daniel Boyland	
Kal Bohn	Stefan Jendersie	
Pauline Barras	Sydney Carr	
	Rachel Worthington	
	Alice Hill	
	Eline Zweers	

PROGRAMME

Wednesday, February 14, 2024		
14:00-14:15	**SIRG 2024 Welcome and Introduction** Becks Hall	
14:15 - 15:15	**Session 1: Hydrology**	
14:15	Alice Hill	Melting rivers: what changes to New Zealand's snow and ice may mean downstream
14:30	Todd Redpath	Resolving and reconciling snow water resources in complex alpine terrain from stereo satellite imagery
14:45	Jono Conway	Forecasting snowmelt in New Zealand
15:00	Oliver Wigmore	Snow drifts as a driver of alpine plant productivity
15:15-15:45	Afternoon tea	
15:45-17:15	**Session 2: Sea ice** Becks Hall	
15:45	Pauline Barras	Sea ice freeboard estimation and snow depth validation campaign in the western Ross Sea
16:00	Stefan Jendersie	Sea ice production in Terra Nova Bay and its far-reaching impacts in the Ross Sea and beyond
16:15	Natalie Robinson	Two contrasting seasons under ice
16:30	Jacqui Stuart	A glimpse into the future: how the time of year that sea ice forms influences associated microalgal communities
16:45	Kal Bohn	Interactions between sea ice ridging & outlet glacier dynamics
17:00	Julia Martin	The influence of snow on Antarctic sea ice evolution: drone-based mapping of the snow surface temperature
Before dinner	Orientation at NIWA Lauder for those staying at NIWA Lauder.	
18:00-onwards	Pizza dinner at Duncans pizza oven – 139 Lauder Flat Road.	

Thursday, February 15, 2024		
8:00-9:00	Breakfast at Becks Hall / NIWA Lauder hostels	
9:00-10:15	**Session 3: Southern Alps Glaciers and Climate** Becks Hall	
9:00	Nicolas J. Cullen	What problems do the demise of accumulation zones of glaciers in the Southern Alps pose for future projections of glacier retreat?
9:15	Alison Spera	The role of avalanche deposition on the mass balance of Rolleston glacier, Arthur's Pass, New Zealand
9:30	Ellorine Carle	Changes on Fox Glacier/Te Moeka o Tuawe and tributaries, 2017-2022
9:45	Heather Purdie	Heat exchange inside crevasses at a temperate alpine glacier
10:00	Tim Kerr	Mountainside temperature lapse rate measurements
10:15-10:45	Morning tea	

10:45-12:00	**Session 4: Remote Sensing of the Cryosphere** Becks Hall	
10:45	Jim Salinger	Effects of the Recent Heatwaves on the South Island glaciers
11:00	Ziyi Zhang	Consistency evaluation of MODIS and VIIRS snow cover products
11:15	Daniel Boyland	Using Synthetic-aperture Radar to monitor the end of summer snowline of New Zealand glaciers
11:30	Pablo Fuchs	Detection of broadband albedo of dirty snow and ice surfaces in high mountain areas using medium-resolution satellite imagery
11:45	Pascal Sirguey	Advancing satellite photogrammetric mapping of snow depth: a comparative study between Pléiades PHR and neo in alpine terrain
12:00-13:00	Lunch break	
13:00-14:00	**Session 5: Ice Shelf and Ice Dynamics** Becks Hall	
13:00	Martin Forbes	Stuck between two walls – what happens within rifts
13:15	Lijuan Wang	Estimating marine ice thickness beneath the Amery Ice Shelf from airborne radio-echo sounding
13:30	Rachel Worthington	An investigation into the effects of anisotropy: experimental deformation of ice from the shear margin of the Priestley Glacier
13:45	Madi Fleming	A new ice deformation technique: intermittent experiments using incremental strain
14:00-14:45	Afternoon tea	
14:45-16:00	**Session 6: Climate Change and Adaptation** Becks Hall	
14:45	Marte Hofsteenge	Moisture sources of snowfall in coastal Victoria Land, Antarctica, and the impact of sea ice anomalies
15:00	Anita Bentley	The response of seasonal snow to climate change in the Southern Alps of New Zealand
15:15	Sydney Carr	Projected future changes in peak flows and implications for climate change allowances
15:30	Christian Zammit	Update on climate change projections for New Zealand
15:45	Blair Fitzharris	Global warming: how to respond to likely changes in snow and ice?
16:00-16:15	Mini break	
16:15-17:00	**Special zoom session from Antarctica** Becks Hall	
16:15-17:00	Christina Hulbe, Dave Prior + students	Tere Tipako Tio: Rapid Extensive Antarctic Ice Sampling
17:00 - 18:00	**Dinner and medal presentation** Becks Hall – leave hall tidy after dinner	
19:00 onwards	**Conference social –** including swimming/walking options in/around Blue Lake Vulcan Hotel St Bathans	

Friday, February 16, 2024		
8:00-9:00	Breakfast and **clean/tidy NIWA houses and Becks Hall kitchen**	NIWA Hostel / Becks Hall
9:00-10:00	Tour of NIWA Lauder scientific facilities	NIWA Lauder main building
10:00-10:30	Morning tea	NIWA Lauder main building
10:30-12:00	Drive from Lauder to Clyde stopping at some gold-mining/ irrigation points of interest on the way – may involve a short walk.	NIWA Lauder to Clyde Dam
12:00-12:30	Stop for lunch	Clyde Playground & Barbecue Area, Miners Lane, Clyde
12:30-14:00	Tour of Clyde dam	Clyde Dam, 46 Fruitgrowers Road, Clyde
14:00	Drive home!	

ABSTRACTS

SEA ICE FREEBOARD ESTIMATION AND SNOW DEPTH VALIDATION CAMPAIGN IN THE WESTERN ROSS SEA

Pauline Barras[1], Wolfgang Rack[1], Christian Haas[2], Adrian Tan[3], Daniel Price[1]
[1]Gateway Antarctica, University of Canterbury, Christchurch, New Zealand
[2]Alfred Wegener Institute for Polar and Marine Research, Bremerhaven, Germany
[3]Lincoln Agritech Ltd, Lincoln, Canterbury, New Zealand

The western Ross Sea is an area characterized by the presence of several important coastal polynyas. Because polynyas processes are significant drivers of the sea ice production in the Southern Ocean, they can have a crucial impact on sea ice trends, and in consequence, on the global ocean circulation and climate. Polynyas are very dynamical areas, a strong ice thickness gradient can be observed, with heavily deformed ice at the margins. However, obtaining a good estimation of the ice thickness to get a precise value of the ice volume created, melted, and exported is still an ongoing issue. The satellite ICESat-2, launched by the NASA in September 2018 was designed to provide a profiling of the Earth's surface with a high resolution and accuracy. Its lasers are reflected at the top of the surface overflown, and by calculating the height difference between the sea surface and the ice/snow surface, an estimation of the total freeboard can be obtained. By using the hydrostatic equilibrium equations, the ice thickness can then be calculated. However, several limitations can be encountered during this process, such as the presence of clouds, the inaccuracy of the surface type classification, and uncertainties regarding the snow layer density and depth.
I will be presenting some of the preliminary results of a flight campaign above the western Ross Sea equipped with a snow radar, a laser altimeter and a camera, and the main hypothesis and objectives of my PhD.

THE RESPONSE OF SEASONAL SNOW TO CLIMATE CHANGE IN THE SOUTHERN ALPS OF NEW ZEALAND

Anita Bentley[1]
[1]University of Otago

Increasing variability in seasonal snow poses growing uncertainty for ski seasons, impacting small club ski fields that have a long and valued history of recreational activity. This study addresses a research gap by rescuing archived ski patrol observations to quantify changes in the seasonal snowpack at Craigieburn Valley Ski Field. The Virtual Climate Station Network (VCSN) also enables a comprehensive seasonal snow climatology to be established.

Despite a significant increase in the mean annual air temperature of New Zealand from 1991 to 2019, the gridded mean annual air temperature at 1600 m at Craigieburn remains stable at 4.7 °C. Annual precipitation averages 1544 mm, with 78% falling as rain and 22% as snow. Seasonal snowfall proportions (July to September) vary from 22% to 83%. Rescued ski patrol data reveals a small but significant annual decrease in mean snow depth of 38.7 cm by 1.3 cm over a 29 year period, projecting a mean snow depth of 0 cm by 2045. Conversely, there is no trend in the total seasonal snow accumulation over the study period. Snowfalls greater than 15cm contribute to 50% of seasonal snow accumulation on average, and snowfalls greater than 32 cm contribute to 15% of seasonal snow accumulation on average. Seasons that experience more of these events tend to have higher seasonal snow accumulation and mean snow depth. Snow-bearing Kidson types are T and TSW, but the most frequent Kidson type over all seasons is H. Analysis of the three established regimes (trough, zonal, and blocking) showed a slight increase in the blocking regime over the study period and a significant increase in the Kidson Type HE, which tends to result in higher temperatures that are not conducive to snowfall.

INTERACTIONS BETWEEN SEA ICE RIDGING & OUTLET GLACIER DYNAMICS

Kal Bohn[1], Wolfgang Rack[1], Daniel Price[1]
[1]Gateway Antarctica, University of Canterbury

The goal of this investigation is to explore a specific type of sea ice-landfast ice interaction: how the ridging of sea ice and the dynamics of outlet glaciers affect each other. This study will focus on use of field data and remote sensing, and will involve two investigatory paths. One path will investigate sea ice ridging over a study area on the East Antarctic coast, using ICESat-2 products and statistical methods to estimate rates of ridging over time, and validating estimates with field data. This path might also involve an attempt to compare sea ice rheology models against the observation-based statistical estimations. The second path will assess the dynamical behaviour and mass balance of outlet glaciers in the study area, using offset tracking applied to Sentinel-1 SAR products, field measurements of surface velocity, ERA5 snow accumulation products over the glacier catchments, and incorporating an existing DEM and bed topography data. The later stages will combine the observation-based results of the two paths to investigate a possible relation between sea ice ridging and outlet glacier discharge. A final stage of investigation could also involve attempting to incorporate a more theoretical approach, drawing on sea ice rheology and using the previous observational results to inform force-balance and momentum-conservation calculations. This exploration aims to provide a valuable observation-focused East Antarctic case study on how sea ice ridging and outlet glacier dynamics are influenced by each other, with potential to expand to also incorporate some rheology-based exploration.

USING SYNTHETIC-APERTURE RADAR TO MONITOR THE END OF SUMMER SNOWLINE OF NEW ZEALAND GLACIERS

Daniel Boyland[1]., Wolfgang Rack[2]., Heather Purdie [3].
[1]School of Earth & Environment, University of Canterbury, Christchurch

The mass balance of New Zealand glaciers has been estimated indirectly using aerial photography and optical remote sensing. These indirect methods have a number of limitations that can be partly overcome using synthetic-aperture radar (SAR), which is hardly influenced by atmospheric conditions, and can therefore expand the temporal and spatial resolution of mass balance measurements.

The aim of this honours project was to investigate the usefulness of SAR for monitoring the End of Summer Snowline (EOSS) of New Zealand glaciers, and whether SAR data, acquired every 12 days, independent of clouds, are able to correct for any uncertainties in the annual aerial photographic survey conducted by NIWA. The snowline dynamics were monitored at the end of summer to determine whether the EOSS survey was acquired at a representative time. The focus of this research was on Tasman Glacier, for the years 2017 and 2018, which had contrasting EOSSs.

Radar backscattering profiles were taken along the flowline to measure the transition between ice and snow. Climate data was modelled for Tasman Glacier using the automatic weather stations (AWS) at Mount Cook Village and Franz Josef Village to understand how temperature and precipitation influence backscattering. The 2017 snow/ice transition line was found to be at the same elevation for both the SAR image and the aerial photograph. The 2018 EOSS was more difficult to measure with SAR, due to the presence of firn from the previous mass balance year. Both temperature and precipitation significantly affected backscattering values.

CHANGES ON FOX GLACIER/TE MOEKA O TUAWE AND TRIBUTARIES, 2017-2022

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

Since 2008, Fox Glacier/Te Moeka o Tuawe has entered a period of rapid retreat, with the glacier presently at its shortest ever recorded length. Using five high resolution DEMs acquired on a roughly annual basis between 2017 and 2022, surface elevation changes and velocities are characterized on the Fox Glacier, as well as over ice and snow-covered areas of tributary valleys. The results provide the widest scale, detailed maps of elevation change across the entire glacier complex for 2020-2022 and lower icefall for 2017-2022, revealing highly dynamic spatial and temporal patterns of ablation, movement of crevasses, and snow accumulation. The lower Fox Glacier, especially in the Victoria Flat area, exhibited substantial downwasting of up to 100 m over the study period, and the icefall's margins shrank by as much as 50 m. In the adjacent valleys of the Victoria and the Mascarin Glaciers, similar evidence of downwasting was apparent, with the results providing novel data on the dynamics of these relatively unstudied glaciers. The Victoria Glacier showed higher accumulation rates than either the Fox or Mascarin Glaciers over the 2020-2021 and 2021-2022 epochs but has experienced more accelerated and sustained retreat than Fox Glacier over the longer term. Given that New Zealand has experienced intense coupled ocean/atmospheric heatwaves in recent summers, it is anticipated that ice loss on these maritime glaciers will only continue to intensify into the coming years.

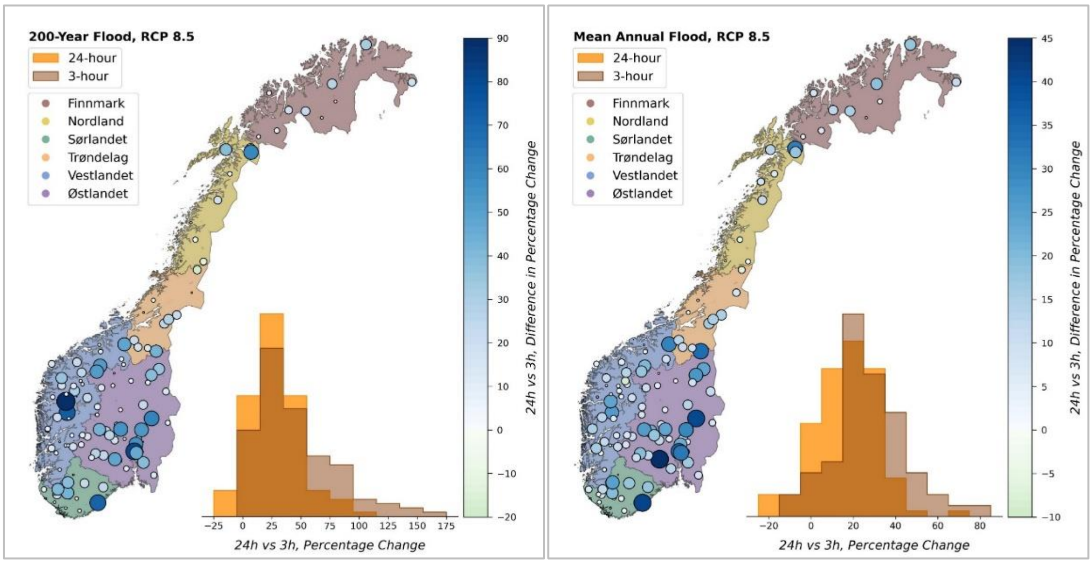
PROJECTED FUTURE CHANGES IN PEAK FLOWS AND IMPLICATIONS FOR CLIMATE CHANGE ALLOWANCES

Sydney Carr[1], Deborah Lawrence[2], Thomas Skaugen[2], Wai K. Wong[2]
[1]University of Washington
[2]The Norwegian Water Resources and Energy Directorate

Short-duration precipitation extremes are intensifying under global climate change. Current recommendations for climate change allowances that account for future changes in flood magnitudes in Norway rely on hydrological simulations run with a 24-hour time step. These projections thereby estimate changes in daily averaged peak flows rather than instantaneous peak flows. This work investigates the consequences of expected changes in precipitation regimes on the current methods used for developing climate change adaptation strategies in Norway.

The Distance Distribution Dynamics hydrological model was run for 120 catchments in Norway using both 3-hour and 24-hour time steps. Input data were derived from 7 EUROCORDEX RCMs based on CMIP5 AOGCMs run under 3 emissions scenarios. The percentage changes in mean annual and 200-year floods between the reference period 1991-2020 and the future period 2071-2100 were estimated using flood frequency analysis. Results indicate that projected changes in 3-hour peak flows are, on average, 50% higher than projected changes in 24-hour peak flows under a high emissions scenario. Consequently, climate change allowances were found to be in a higher category for 56 of the 120 catchments. Machine learning algorithms indicate that climate and catchment characteristics can explain projected increases. A feature selection analysis represents a starting point for future work regionalising the 3-hour results to ungauged catchments.

Given the expected increase in frequency and intensity of extreme rainfall events throughout New Zealand, this scope of work can be leveraged in ongoing climate change investigations aimed towards enhancing long-term flood forecasts for both snow- and rainfall-dominated catchments.



BETTER RUNOFF AND HAZARD PREDICTIONS THROUGH NATIONAL-SCALE SNOWMELT FORECASTING

Jono Conway[1], Doug Booker[1], Trevor Carey-Smith[1], Céline Cattoën-Gilbert[1], Nicolas J. Cullen[2], Richard Essery[4], Yinjing Lin[1], Keith Musselman[5], Rasool Porhemmat[1], Todd Redpath[2], Pascal Sirguey[3]
[1]NIWA
[2]School of Geography, University of Otago
[3]National School of Surveying, University of Otago
[4]University of Edinburgh
[5]University of Colorado

This talk will introduce a new MBIE Smart Ideas project **"Better runoff and hazard predictions through national-scale snowmelt forecasting"**. The project aims to develop a state-of-the-art snowmelt forecast system to enable more accurate and confident forecasts of river flow and alpine hazards across New Zealand. Forecast outputs will provide both national-scale context and local-scale detail, along with full quantification of uncertainty in the rate, volume, and timing of snowmelt. Robust snowmelt forecasts will enable end-users in hazard, energy, agriculture, and tourism domains to better respond to rain-on-snow impacts on river flows and alpine hazards.

Snowmelt forecast will be generated through physics-based ensemble snow modelling that will assimilate newly developed satellite remote sensing products to quantify initial snow cover and depth. Cutting-edge ensemble numerical weather forecast data will be used as snow model input to provide robust uncertainty estimates. Hydrometeorological and snow data from high-elevation weather stations will be used to test the system, ensuring extreme snowmelt rates observed in historical records are well simulated. Given the sparse observation network and large area of New Zealand's alpine domain, our system is ideally placed to provide a step-change in forecasting snowmelt processes with fine detail at a national scale.

The system will be implemented in NIWA's operational multi-hazard forecasting system, ensuring forecasts are readily available to end-users and easily ingested into river flow and flood inundation models. The project will include case study catchments where we will test the methods and benefits of integrating snowmelt forecasts with existing river flow forecasts.

WHAT PROBLEMS DO THE DEMISE OF ACCUMULATION ZONES OF GLACIERS IN THE SOUTHERN ALPS POSE FOR FUTURE PROJECTIONS OF GLACIER RETREAT?

Nicolas J. Cullen[1]
[1]School of Geography, University of Otago

Traditional mountain glacier theory suggests that a change in climate due to warming typically leads to an alpine glacier retreating to a higher elevation where it is able to reach a new equilibrium with the modified climate. This response is dependent on a glacier responding to the given climate forcing while maintaining what are commonly known as accumulation and ablation zones, which are separated by an equilibrium line altitude. It is becoming increasing apparent from the range of observations being taken of glaciers in the Southern Alps, whether these are from remote sensing or in situ observations, that the upper regions of many of our glaciers are no longer areas of accumulation. Using mass balance and climate observations from Brewster Glacier, supported by mass balance modelling, the implications of the demise of the accumulation zone are explored and questions posed on what this might mean for future projections of glacier retreat in the Southern Alps.

GLOBAL WARMING: HOW TO RESPOND TO LIKELY CHANGES IN SNOW AND ICE?

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

Global warming is proceeding at an unprecedented rate. Some sources claim that 2023 was the warmest year in 100,000 years. Over the last five years New Zealand experienced the most intense coupled ocean/atmosphere heatwaves on record. Average temperature anomalies over land and sea were +1.2 to 1.4°C above average. As predicted by the Intergovernmental Panel on Climate Change (IPCC), such warming is highly likely to continue. How are we going to respond to the very likely massive changes to our seasonal snow and glacier resources? The main option is to try to adapt. This strategy receives far too little attention in New Zealand, compared with the constant focus on mitigation. What can we do to save the ski industry? What will happen to our hydroelectricity production? What about infrastructure and planning for probable maximum floods? What about snow avalanches and other cryosphere hazards? Alternatively, should we begin to engage in geo-engineering to help cool the planet? A few of these strategies are examined, with lessons from Nature's way of accomplishing such outcomes.

A NEW ICE DEFORMATION TECHNIQUE: INTERMITTENT EXPERIMENTS USING INCREMENTAL STRAIN

Madi J. Fleming[1], David J. Prior[1], Sheng Fan[1], Brent Pooley[1], Hamish Bowman[1], Rachel Worthington[1]
[1]Department of Geology, University of Otago, Dunedin, New Zealand

Ice, when experimentally deformed, commonly fractures when reaching high strains of >40%. Sample fracture is the prevailing issue facing experimentalists when attempting to replicate natural strains. Obtaining higher strains experimentally can provide further insight into microstructural development, therefore we suggest a new technique to prevent ice fracturing: intermittent experiments. This comprises stopping r**ep**experiments after an increment of strain, milling the sample, and then repeating this using the same strain increment. This method provides cumulative strain over 5% strain increments with the aim to prevent excessive sample bulging, which accommodates fracture at high strains. Currently, these intermittent experiments have successfully reached a cumulative 17% strain and suggests this is a useful method to avoid fracture. However, the approach of stopping and starting experiments introduces issues with grain relaxation; exposing the sample to warmer temperatures for <1 minute, coupled with the natural sample decompression from the rig could potentially emphasise microstructural changes caused by grain relaxation.

STUCK BETWEEN TWO WALLS – WHAT HAPPENS WITHIN RIFTS

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

Rifts are large, through-cutting, laterally propagating, fractures in ice shelves. They propagate in response to stress and split the floating ice creating new internal boundaries. Both glaciostatic and hydrostatic overburden act on these internal boundaries, or rift walls, and because they have different patterns of depth-dependence, this results in net inward pull. Rifts are also observed to be filled with melange, a conglomerate of frozen seawater, blocks of glacier ice and accumulated snow, which is generally an order of magnitude thinner than the surrounding ice shelf. The contribution of melange to rift processes is unknown, with some speculating it "glues" rift walls together and others that it pushes out on the rift walls.

In this work, we wade into this debate using two numerical approaches to investigate the role of melange. First, a novel set of numerical tools for simulating rift propagation with specific attention to conditions on the internal boundaries is used to investigate the melange contribution to the rift walls required to cause observed rift propagation. Then, a more traditional ice flow model with internal rift boundaries included is used to investigate the required mélange contribution to reproduce observed rift widening. Do these two approaches result in matching roles for melange and solve the debate? You will just have to wait for this talk to find out.

Figure 1: photograph by Andy Van Kints (retrieved from www.bas.ac.uk)

DETECTION OF BROADBAND ALBEDO OF DIRTY SNOW AND ICE SURFACES IN HIGH MOUNTAIN AREAS USING MEDIUM-RESOLUTION SATELLITE IMAGERY

Pablo Fuchs[1], Heather Purdie[1], Shelley MacDonell[1], Marwan Katurji[1], Ruzica Dadic[2,3], Brian Anderson[3]
[1]School of Earth and Environment, University of Canterbury, Christchurch, New Zealand
[2]WSL Institute for Snow and Avalanche Research, Davos Dorf, Switzerland
[3]Antarctic Research Centre, Victoria University, Wellington, New Zealand

---

Light-absorbing impurities (LAI) significantly influence melt and the energy budget of snow and ice surfaces through the albedo feedback. Ground observations of the shortwave radiation fluxes obtained from a pyranometer pair provide point-scale albedo data for a limited number of sites, but they are not always available over long, continuous periods. Satellite-based retrievals from remote sensing data can overcome these limitations and provide snow and ice albedo to investigate the spatial distribution and the temporal evolution of this variable in remote areas. The aim of this research is to validate and assess the performance of satellite albedo retrievals for dirty snow and ice surfaces. The proposed method uses applications-ready atmospherically corrected surface reflectance data from the Harmonized Landsat Sentinel-2 product as input and includes two parameterizations for the anisotropic correction and three narrowband to broadband conversion algorithms. Surface anisotropy is characterized using empirical models of the Bidirectional Reflectance Distribution Function (BRDF) that differ for snow and ice surfaces and depend on the number of spectral bands used to estimate broadband albedo. The albedo retrievals are validated against ground-based albedo measurements from several automatic weather stations in high mountain areas. The results show that the Knap method, which considers two spectral bands (green and near-infrared), performed best with $R^2 = 0.92$, followed by the Liang (five bands, $R^2 = 0.91$) and the Feng (four bands, $R^2 = 0.80$) methods. In this talk, we show that the albedo retrieval method is suitable for future efforts to estimate the impact of LAI on melt and the surface energy balance of snow and ice.

MELTING RIVERS: WHAT CHANGES TO NEW ZEALAND'S SNOW AND ICE MAY MEAN DOWNSTREAM

Alice F. Hill[1], Bruce Dudley[2], Emma Wallace[3]
[1]NIWA – Nelson
[2]NIWA – Christchurch
[3]University of Birmingham

"Mountains are the water towers of the World" is a widely accepted principle in hydrology because mountains store snow and ice and release meltwater downstream at different times of the year. The Southern Alps hold most of Aotearoa-New Zealand's snow and ice reservoirs, and this frozen water lies at the headwaters of many large rivers. Snow lines are rising, and glaciers are shrinking as climate change continues unabated. Changes in the timing, flowpaths and amount of meltwater have potential downstream impacts to ecosystems, taonga species, agriculture, tourism, hydropower, and environmental management which lead to concerns about regional water security. If we rely on meltwater to meet water resource demands, what does the future hold for water supplies amidst a changing and uncertain climate?

Understanding meltwater's role in downstream water resources is ever more important in drier regions of New Zealand that are already experiencing water supply pressures. In Canterbury, increasing water extraction due to land use intensification and downstream agricultural practices has already heightened concern by end users over future water vulnerabilities. To begin clarifying climate sensitivity of flow in this region here we quantify the seasonal role of snow and ice source waters in the Waimakariri and Rangitata basins using hydrochemistry and isotope tracer-based mixing models. We present preliminary findings on the temporal and spatial variation of meltwater contributions to river flow in these major watersheds based on sampling over a 2-year period (2021-2023). This work provides a framework for further research in evaluating water resource climate sensitivity on the Canterbury Plains, as well as additional context in applying the "mountain water tower" paradigm to New Zealand.

MOISTURE SOURCES OF SNOWFALL IN COASTAL VICTORIA LAND, ANTARCTICA, AND THE IMPACT OF SEA ICE ANOMALIES

Marte Hofsteenge[1], Nicolas Cullen[1], Marwan Katurji[2]
[1]School of Geography, University of Otago, Dunedin
[2]School of Earth and Environment, University of Canterbury, Christchurch

Snowfall is an important component of the mass balance of ice sheets and glaciers in Antarctica. In the McMurdo Dry Valleys in southern Victoria Land, snowfall impacts the inter-annual variability of melt of the glaciers. In this study, we use a Lagrangian moisture source diagnostic to study the dominant pathways of moisture transport and the sources of moisture of precipitation in coastal Victoria Land of Antarctica. The objective is to gain insights into the unique conditions of the McMurdo Dry Valleys and highlight differences in precipitation patterns and moisture sources compared to other areas in coastal Victoria Land.

Spatial correlation analysis shows that precipitation in northern and southern Victoria Land are poorly correlated, indicating that they receive precipitation through different pathways. Trajectory analysis on ERA5 data confirms this: precipitation in Southern Victoria occurs often during southerly flows because of cyclonic disturbances in the ross sea, while precipitation in northern Victoria land has a more northern origin.

Antarctic snowfall is expected to change with a warming climate, through the increase in atmospheric moisture content with rising temperatures but also through enhanced evaporation due to a reduced sea ice cover. Since Northern and Southern Victoria land receive moisture through different pathways, anomalies in evaporative sources might therefore impact the regions in different ways. We investigate the impact of sea ice anomalies on the moisture uptake, such as the reduced ice conditions in 2023.

MOUNTAINSIDE TEMPERATURE LAPSE RATE MEASUREMENTS

Tim Kerr[1], Heather Purdie[2], Drew Lorrey[3]
[1]Rainfall.NZ
[2]University of Canterbury
[3]NIWA

Temperature lapse rates are being measured up four mountainsides in the Southern Alps.

Representative temperature lapse rates are needed for snow and ice modelling, for example in estimating temperatures during past glaciations.

Globally, mountainside temperature measurement campaigns have shown that lapse rates are spatially and temporally variable. This means local measurements are needed to determine locally-appropriate lapse rates.

In New Zealand, previous lapse rate assessments have been limited by the low-elevation bias of the national network of climate stations. Alternative efforts have estimated lapse rates from nearby pairs of climate stations at high and low elevations, assuming it is reasonable to use two points to describe a relationship.

This measurement exercise has been designed to extend previous efforts of assessment of lapse rates used in Southern Alps applications.

On each mountainside, ten logging temperature sensors have been installed at 100 m vertical intervals. The sensors are mounted 2 m above the ground within solar radiation shields and log every 30 minutes. Sites are inspected and data downloaded every 6 months. Two years of measurements have been collected so far, with the intention to collect at least one further year of data.

Results so far indicate a long-term lapse rate of -5 °C/km is generally reasonable but will be incorrect on any particular day (see figure below), hour or section of mountainside.

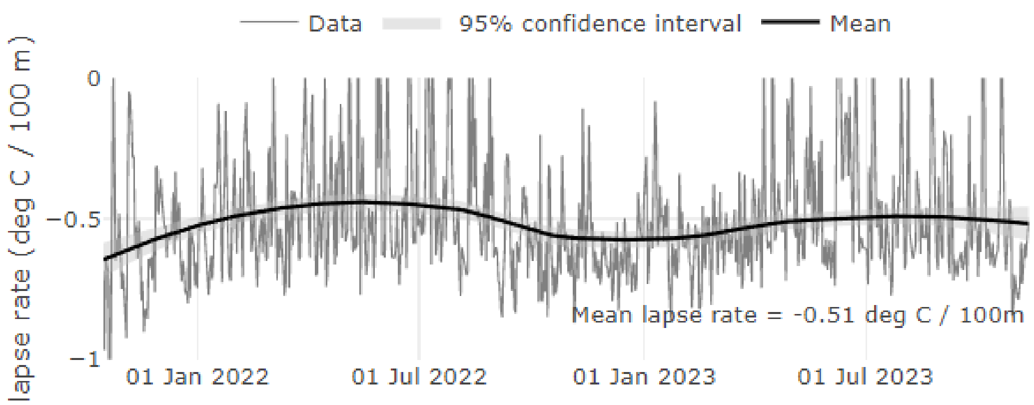


FIGURE 2. DAILY LAPSE RATES FROM THE MT PHILISTINE (ARTHURS PASS) TEMPERATURE LAPSE RATE MEASUREMENT NETWORK.

THE INFLUENCE OF SNOW ON ANTARCTIC SEA ICE EVOLUTION: DRONE-BASED MAPPING OF THE SNOW SURFACE TEMPERATURE

Julia Martin[1], Ruzica Dadic [1, 2], Roberta Pirazzini[3], Lauren Vargo[1], Oliver Wigmore[1], Martin Schneebeli[2], Brian Anderson[1], Henna-Reetta Hannula [3], Huw Horgan[2]
[1] Antarctic Research Centre, Victoria University of Wellington, Wellington, New Zealand
[2] WSL Institute for Snow and Avalanche Research SLF, Davos, Switzerland
[3] Finnish Meteorological Institute, Helsinki, Finland

Antarctic sea ice is a key parameter for Earth's energy balance. The snow cover dominates the variability of sea ice's thermal and optical properties and is essential to understanding sea ice growth and decay. It governs the energy and mass fluxes between the ocean and the atmosphere, sea ice thickness, bottom water formation, and ocean circulation. The current lack of data on the physical properties of the snow and its effect on sea ice leads to large uncertainties in the coupling of climate feedback and results in significant biases in model representations of the sea ice cover.

To increase our understanding of the snow-sea ice - interactions, we quantitatively investigated the physical properties of snow on Antarctic sea ice (McMurdo Sound, October – December 2022) using a wide range of ground-based and airborne instrumentation.

Here, we present a drone-based method and results for infrared mapping of the snow surface temperature combined with ground surveys of snow depth and sea ice thickness.

We used a DJI Matrice 30T drone to simultaneously take RGB and infrared images of the surface and ice of 5 different 200x200 m measurement fields with different freezing histories. We georeference the drone imagery using ground targets and a mobile DGPS system to account for the vertical tidal displacement. We correct the temporal temperature changes during the flight using hot ground targets and mobile infrared sensors positioned within the drone footprint. We then explore the link between surface temperatures and the spatial variability of snow depth and ice thickness.

HEAT EXCHANGE INSIDE CREVASSES AT A TEMPERATE ALPINE GLACIER

Heather Purdie [1]., Tim Kerr[2]., Paul Bealing [1]., Peyman Zawar-Reza [1]., Marwan Katurji [1]
[1] School of Earth & Environment, University of Canterbury, Christchurch
[2] Rainfall.NZ, Christchurch

Previous research found positive air temperatures inside crevasses in the accumulation area of an alpine glacier, including ≥5°C at night without the effects of radiative heating (Purdie et al., 2022). Here are results from our fourth field campaign 16-24 February 2023. Following previous methods, we instrumented crevasses to measure air temperature and 2D wind speed. We installed automatic weather stations on the glacier surface, and used a drone to map surface elevation, from which 3D models of the glacier accumulation area and crevasses were constructed. Results reported focus on night-time case studies of in-crevasse temperature and wind; data which were also used to estimate the turbulent sensible heat flux (Qh). We use the done data to calculate and compare 2D and 3D surface areas.

Relationships are observed between in-crevasse wind (horizontal and vertical) and in-crevasse heating. Lower wind speed results in stratified temperature structures, with cooler air below 6m, while stronger wind pushes warm air (>2°C) down to 10+m. Using these data, we calculate Qh at each depth, after subtracting the energy required to raise the temperature of the crevasse walls to melting point. The average overnight Qh is 23-8 Wm^{-2} in the upper 4 m, and ≤ 3 Wm^{-2} at depth. When comparing the 2D and 3D crevasse surface areas, we found the 3D area contained an additional 2832 m^2 over which energy exchange could occur. Our next step is to explore the implications of these results to the wider accumulation area.

Purdie H., Zawar-Reza P., Schumacher B., Katurji M., Kerr T., Bealing P. (2022). Variability in the vertical temperature profile of crevasses at an alpine glacier. *Journal of Glaciology* 69(274): 410-424.

RESOLVING AND RECONCILING SNOW WATER RESOURCES IN COMPLEX ALPINE TERRAIN FROM STEREO SATELLITE IMAGERY

Todd Redpath[1], Pascal Sirguey[2], Jono Conway[3], Nicolas Cullen[1]
[1]School of Geography, University of Otago
[2]National School of Surveying, University of Otago
[3]National Institute of Water and Atmospheric Research

Satellite photogrammetric mapping (SPM) represents a measurement step-change in snow hydrology, providing new and improved insights into processes and supporting ongoing model development, calibration, and validation. This research leverages archived Pléiades tri-stereo imagery and the DEM differencing approach to map snow depth in the central Southern Alps through the winter of 2012. Snow depth maps were produced for five dates from early- (June) to peak-accumulation (October) for the upper Jollie Catchment. The photogrammetric workflow includes rigorous uncertainty analysis and quality assessment. Snow depth was converted to snow water equivalent (SWE) via an empirical density function, yielding hypsometric SWE distributions for sub-basin hillslope units. Assessment of photogrammetric performance revealed a measurement bias typically on the order of centimetres, and a standard deviation on the order of tens of centimetres, comparing favourably with snow depths on the order of metres. Results reveal that peak snow depth and SWE generally occur below ridgeline level, reflecting the influence of redistribution and preferential accumulation. Combined with basin hypsometry, this means that most of the SWE volume resides at mid-elevations within the catchment. Scaling the analysis up to the full archived image domain (372.6 km2 of the upper Pukaki Catchment) for the date nearest peak accumulation (October 4), yields a SWE volume of approximately 492,000,000 m3, equivalent to ~27 days of the mean summer inflow to Lake Pukaki. Within the full elevation range of 700 to 3724 m, 62% of the total SWE volume resides between 1800 and 2400 m (38% of the mapped area).

TWO CONTRASTING SEASONS UNDER ICE

Natalie Robinson[1], Brett Grant[1], Ollie Twigge[1], Craig Stewrt[1], Greg Leonard[2], Ken Ryan[3]
[1] NIWA – National Institute for Water & Atmospheric Research
[2] School of Surveying, University of Otago
[3] School of Biological Sciences, Te Herenga Waka

The 2022 Antarctic sea ice growth season was unprecedented in the satellite era, including the lowest pan-Antarctic September extent on record at that time. In McMurdo Sound the fast ice cover formed and re-formed several times until the end of August, when a stable cover was finally established – four months later than usual.

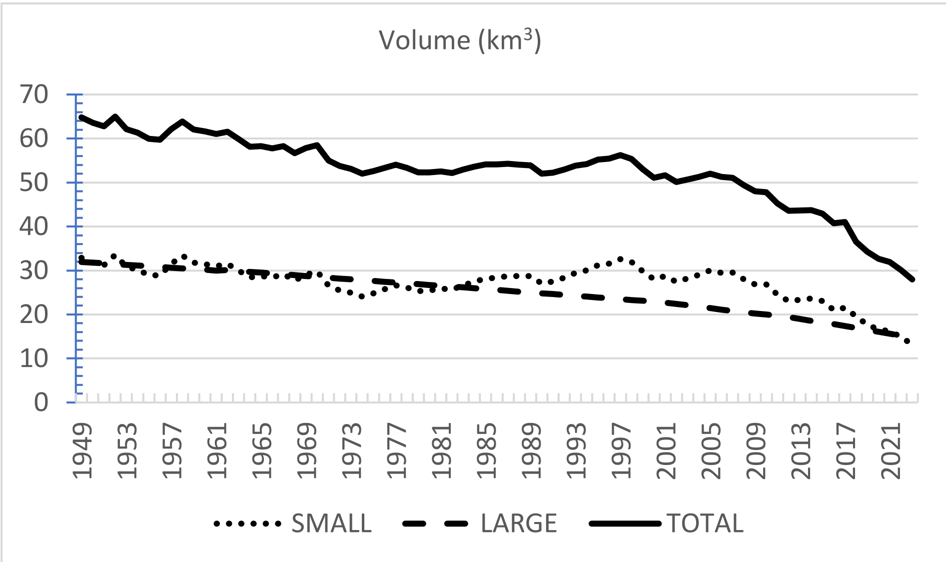
This local effect was driven by a series of southerly storms that drove extreme activity of the McMurdo Sound and Ross Sea polynyas. As a result, new sea ice growth occurred throughout the winter, driving deep and persistent brine rejection. This offset in timing also affected biological recruitment of, and into, the sub-ice platelet layer (SIPL). This resulted in two highly differentiated SIPL regimes which were exploited for surface-based sampling in October and November. Here we present new ocean data from southern McMurdo Sound, captured throughout this unusual season, and through the following, more typical, 12-month period, with a novel seafloor-mounted mooring.

Instead of the normal homogenising of the water column through the autumn months, significant spatial and temporal variability persisted through to the end of the winter 2022 months, to depths as great as 250 m below sea level. Further analysis of the two timeseries will be necessary to assess whether the unusual oceanographic signals were locally-generated or advected in from the wider western Ross Sea.

EFFECTS OF THE RECENT HEATWAVES ON THE SOUTH ISLAND GLACIERS

Jim Salinger[1], Blair Fitzharris[2]
[1]School of Geography, Earth and Environmental Science, Victoria University of Wellington
[2]Department of Geography, University of Otago

During the four austral warm seasons (NDJFM) of 2017/18, 2018/19, 2021/22 and 2022/23 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 - 1.4°C above average. Common to all four events were maximum sea surface temperature (SST) anomalies to the west of the South Island of NZ. Atmospheric circulation anomalies showed a pattern of blocking high pressure over the Tasman Sea and Pacific Ocean to the south, and south-east of NZ, and reduced trough activity over and to the east of NZ, accompanied by strongly positive Southern Annular Mode conditions. The end of summer snowline (EOSS) time series is used to estimate Southern Alps glacier mass balance from 1977 to 2021 for $EOSS_{Alps}$. Regression relationships are employed to calculate $EOSS_{Alps}$ for 2021, 2022 and 2023. Ice volume is calculated by the methods of Chinn et al (2012). Ice volume loss in the Southern Alps for the small and medium glaciers is estimated to be 4.5 km^3 in 2017/18, 2.3 km^3 in 2018/19, 1.8 km^3 for 2021/22 and 2.2 km^3 in 2022/23. The total loss from 2017/18 to 2022/23 is 13.1 km^2 for the recent warm seasons 2017 to 2023. This is a reduction of32% of the total ice volume of the Southern Alps compared with the volume of March 2017 and is the largest ice loss in any 5-year period since 1949. Total ice volume declined from 41 km^3 to 28 km^3.



Ice volume loss in the Southern Alps - annual ice volume (km^3). Total for all (solid), large (dashed) and small (dotted) glaciers.

Chinn, T.J., Fitzharris, B.B., Salinger, M.J, & Willsman, A. 2012. Annual ice volume changes 1976–2008 for the New Zealand Southern Alps. *Global and Planetary Change*, 92-93: 105-118. https://doi.org/10.1016/j.gloplacha.2012.04.002.

ADVANCING SATELLITE PHOTOGRAMMETRIC MAPPING OF SNOW DEPTH: A COMPARATIVE STUDY BETWEEN PLÉIADES PHR AND NEO IN ALPINE TERRAIN

Pascal Sirguey[1], Aubrey Miller[1], Todd Redpath[1,2]
[1]National School of Surveying, University of Otago
[2]School of Geography, University of Otago

The Matariki project presents an innovative approach to automate Aerial and Satellite Photogrammetric Mapping (APM/SPM), aiming to construct repeatable, sub-meter accuracy Digital Surface Models (DSMs) and resolve surface elevation changes. Mapping snow depth in challenging alpine terrain poses a boundary-testing application of 3D-Change Detection (3D-CD), especially with steep topography and poorly contrasted targets. Additionally, achieving repeatable coherent mapping at a sub-pixel level becomes imperative to discern subtle yet significant elevation changes.

In the context of the Pléiades Neo Challenge, we evaluate the performance of SPM in comparison with Pléiades PHR and the latest generation Pléiade Neo (PNEO) for mapping snow depth over Kawarau/The Remarkables. Tri-stereo acquisitions of snow-covered terrain from PHR and PNEO during winter/spring 2022, along with a snow-free acquisition with PHR in 2020, provide a comprehensive dataset for analysis. Utilizing the Matariki Photogrammetric Mapping and 3D Change Detection system (MAP23D), we enable benchmarking and comparisons between the performance of PHR and PNEO.

Our results affirm the efficacy of mapping snow depth with sub-meter accuracy using PHR. Initial processing of PNEO imagery revealed challenges in geometric correction of Primary products, compromising the robustness and accuracy of surface modelling. A collaborative effort with satellite manufacturer Airbus DS, coupled with the performance of MAP23D, facilitated rapid reprocessing of corrective imagery for PNEO. The photogrammetric restitution of PNEO ultimately yielded significantly improved spatial resolution, enhancing the ability to map finer structures in the snow spatial distribution with heightened precision.

THE ROLE OF AVALANCHE DEPOSITION ON THE MASS BALANCE OF ROLLESTON GLACIER, ARTHUR'S PASS, NEW ZEALAND

Alison Spera[1], **Heather Purdie[2]** , Tim Kerr[3] , Wolfgang Rack[4]
[1] University of Canterbury
[2] University of Canterbury
[3] Rainfall New Zealand
[4] University of Canterbury

Avalanches can be an important source of nourishment for cirque mountain glaciers, supplementing their accumulation and delaying melt. However, their contribution to glacier mass balance is often overlooked.

Here we evaluate the effect of avalanche deposition on the Rolleston Glacier mass balance using an Energy Balance Model (EBM) coupled to a mass transport and deposition (MTD) routine. A 12-year climate record (2010 – 2022) was developed and used to drive the model, with temperature lapse rate and a precipitation factor used as tuning parameters. Annual (Bn) and winter balances (Bw) were compared for selected years (2010/11, 2012/13 and 2018/19) with and without the MTD component. Results showed that excluding gravitational processes under-estimated Bw by up to 2.29 m w.e, while activating the MTD yielded Bw estimates on average within 0.97 m w.e of observed measurements. The model replicated the observed spatial distribution of avalanche deposition reasonably well, and we determined that approximately 57% of the average winter balance could be attributed to avalanche deposition.

The EBM model was compared to cumulative mass balance measurements, showing a strong (R2 = 0.9) relationship when coupled to the MTD, compared to a moderate (R2 = 0.65) relationship when the MTD was not utilised. These results demonstrate that including a MTD routine has useful application to simulating more accurate mass balance estimates at alpine glaciers. Future work should include a comprehensive parameter optimisation and sensitivity analysis to further improve model performance.

A GLIMPSE INTO THE FUTURE: HOW THE TIME OF YEAR THAT SEA ICE FORMS INFLUENCES ASSOCIATED MICROALGAL COMMUNITIES

Jacqui Stuart[1, 2], Natalie Robinson[3], Craig Stewart[3], Kirsty F. Smith[2, 4], John Pearman[2], Svenja Halfter[3], Greg Leonard[5], Ken Ryan[1]

1. School of Biological Sciences, Victoria University of Wellington, PO Box 600, Wellington 6140, New Zealand.
2. Cawthron Institute, Private Bag 2, Nelson 7042, New Zealand.
3. National Institute of Water and Atmospheric Research (NIWA), Private Bag 14901, Kilbirnie, Wellington 6241
4. School of Biological Sciences, University of Auckland, Private Bag 92019, Auckland 1142, New Zealand.
5. School of Surveying, Otago University, PO Box 56, Dunedin 9054, New Zealand

The microalgal communities contributing to the base of the marine food web are changing due to global climate related stressors. Unusual southerly storms occurred in McMurdo Sound in mid-2022, causing most sea ice within the Sound to form five months later than in a typical year. This provided a unique opportunity to compare a future "new normal" sea ice environment with current typical conditions. We compared the structure of Antarctic microalgal communities in fast ice and the sub-ice platelet layer (SIPL) in typical 2.2 m thick annual ice, and in new, thinner ~1 m thick ice. Fast ice and SIPL cores were collected using a coring drill for the congelation ice, and a novel SIPL sampling system that preserves structure of the fast/platelet interface. Microalgal communities were characterised using chlorophyll-a, cell concentrations, and high-throughput sequencing metabarcoding. Analyses showed highest biomass at the fast/platelet ice interface in typical ice and lower biomass in the SIPL. In contrast, peak biomass was further from the fast/platelet interface in newer ice, with overall biomass being of similar quantities. There was a substantial shift in dominant microalgal groups observed in new and typical ice environments. In addition, significant differences between fast and SIPL microalgal communities in both ice conditions. With ongoing climate change, it is anticipated that fast ice formation will occur later in autumn/winter. This will have an impact on ice associated microalgal biomass, community composition and diversity. These changes will influence many organisms throughout the food web in Antarctic marine ecosystems.

ESTIMATING MARINE ICE THICKNESS BENEATH THE AMERY ICE SHELF FROM AIRBORNE RADIO-ECHO SOUNDING

Lijuan Wang[1,2,3,4], Xueyuan Tang[3,5], Jingxue Guo[3], Gang Qiao[1,2], Lu An[1,2], Lin Li[3], Jamin S. Greenbaum[6], Christina Hulbe[4], Feras A. Habbal[7], Lenneke M. Jong[8], Tas van Ommen[8], Jason L. Roberts[8], Duncan A. Young[9], Donald D. Blankenship[9], Bo Sun[3]

[1]Center for Spatial Information Science and Sustainable Development Applications, Tongji University, Shanghai 200092, China
[2]College of Surveying and Geo-Informatics, Tongji University, Shanghai 200092, China
[3]Key Laboratory of Polar Science, MNR, Polar Research Institute of China, Shanghai 200136, China
[4]National School of Surveying, University of Otago, Dunedin 9016, New Zealand
[5]School of Oceanography, Shanghai Jiao Tong University, Shanghai 200030, China
[6]Scripps Institution of Oceanography, University of California, San Diego, La Jolla, CA 92093, USA
[7]Oden Institute for Computational Engineering and Sciences, University of Texas at Austin, Austin, Texas 78758, USA
[8]Australian Antarctic Division, Kingston, TAS 7050, Australia
[9]Institute for Geophysics, University of Texas at Austin, Austin, Texas 78758, USA

Ice shelves affect the long-term stability of ice sheets due to their supporting effect on the mass balance of the ice sheets. Marine ice that forms at the base of ice shelves is a significant source of mass gain that affects the dynamics of the ice shelf. We apply the principle of hydrostatic equilibrium to provide a new estimate of the marine ice distribution beneath the Amery Ice Shelf (AIS) in East Antarctica using surface elevation and the meteoric ice thickness obtained from radio-echo sounding (RES) data during the Chinese National Antarctic Research Expedition (CHINARE) between 2015 and 2019. Our new estimates reveal two longitudinal marine ice bands beneath the northwest area of the AIS, spatially consistent with studies conducted 20 years ago, but thinner than marine ice observed in earlier borehole measurements. In addition, a marine ice layer exceeding 30 m in thickness is found beneath the central part of the ice shelf. We speculate that shallow topography beneath the southeastern part of the AIS hinders intrusions of warm water, leading to the accumulation of marine ice at the central AIS. Our results represent the first mapping of marine ice beneath the AIS in nearly 20 years, and will provide important data for numerical models to quantify ice-ocean interaction and material transport in the ice shelf system.

SNOW DRIFTS AS A DRIVER OF ALPINE PLANT PRODUCTIVITY

Oliver Wigmore[1,2], Noah Molotch[2]
[1]Antarctic Research Centre/Te Puna Patiotio, Victoria University of Wellington/Te Herenga Waka
[2]Institute of Arctic and Alpine Research, University of Colorado Boulder

Patterns of alpine plant productivity are extremely variable in space and time. Complex topography drives variations in temperature, wind, and solar radiation. Surface and subsurface flow paths route water between landscape patches. Redistribution of snow creates scour zones and deep drifts, which drives variation in water availability and growing season length. Hence, the distribution of snow likely plays a central role in patterns of alpine plant productivity. Given that these processes operate at sub 1m to sub 10m spatial scales and are dynamic across daily to weekly time scales, historical studies using manual survey techniques have not afforded a comprehensive assessment of the influence of snow distribution on plant productivity. To address this knowledge gap, we used weekly estimates of Normalised Difference Vegetation Index (NDVI), snow extent, and peak snow depth, acquired from uncrewed aerial systems (UAS), at 25cm resolution. We derived six snowpack-related and topographic variables that may influence vegetation productivity; and analysed these with respect to the timing and magnitude of peak productivity. Peak NDVI and Peak NDVI timing were most highly correlated with maximum snow depth, and, snow-off-date. We observed up to a ~30% reduction in peak NDVI for areas with deeper and later snow cover, and a ~11 day delay in the timing of peak NDVI in association with later snow-off-date. Our findings leverage a unique dataset to quantify the importance of snow distribution in driving alpine vegetation productivity, and provide a space for time proxy of potential changes in a warmer, lower snow future.

AN INVESTIGATION INTO THE EFFECTS OF ANISOTROPY: EXPERIMENTAL DEFORMATION OF ICE FROM THE SHEAR MARGIN OF THE PRIESTLEY GLACIER.

Rachel Worthington[1], Dave Prior[1] Rilee Thomas[2] Travis Hager[3] David Goldsby[3]
[1] Department of Geology, University of Otago, Dunedin.
[2] Department of Geology and Geophysics, Woodshole Oceanographic Institute, Woodshole, MA.
[3] Department of Earth and Environmental Science, University of Pennsylvania, Philadelphia, PA.

Fabrics that occur in ice produce significant mechanical anisotropy. Understanding the effect of this is important in producing accurate models for ice streams and glaciers, as shear margins with strong fabrics (compared to internal flow zones with weaker fabrics) are understood to facilitate ice stream flow and stability. Furthermore, many of the numerical models for ice streams tend to have the highest degrees of error within these shear zones. While many studies have used a variety of remote and ground surveying techniques, ice-core observations and numerical modelling methods to better understand the effect mechanical anisotropy has on ice flow, there is almost no experimental laboratory deformation data published on the issue.

We provide data from laboratory experiments showing the significant effect that fabric orientation relative to compression direction has on strain symmetry, mechanical strength, fabric evolution and microstructural characteristics of polycrystalline ice deformed at 3 different strain rates. Our experiments use ice from the Priestley Glacier shear margin, which is characterized by very strong horizontal c-axis maxima sub-perpendicular to the shear plane. Cylinders cored parallel to the c-axis maximum are up to 5 times as strong in axial compression as those cored 45 degrees to the c-axis maximum. Cylinders cored 45 degrees and perpendicular to the c-axis maximum undergo approximate plane strain while cylinders cored parallel undergo pure shear flattening. These results suggest that the anisotropy of ice constrains deformation kinematics. Preliminary analysis of microstructural data shows kink banding is an important deformation mechanism with the 45 degree and perpendicular cylinders. These experiments provide important constraints for modelling parameters.

CONSISTENCY EVALUATION OF MODIS AND VIIRS SNOW COVER PRODUCTS

Ziyi Zhang[1]**,** Todd Redpath[2], Pascal Sirguey[1]
[1]National School of Surveying, University of Otago
[2]School of Geography, University of Otago

NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) instrument, which has provided data for many researchers from different scientific domains for decades, is approaching end-of-life. Thus, applications based on MODIS, such as the mapping of snow-covered areas at regional to global scales, need to transition to image products from alternative sensors such as the Visible Infrared Imaging Radiometer Suite (VIIRS). This research aimed to evaluate the consistency between MODIS and VIIRS snow-cover products for New Zealand and explore potential reasons for discrepancies in support of ongoing snow research in New Zealand. While pixel-level retrievals of NDSI and snow cover fraction appear to be consistent enough to support a calibration between MODIS and VIIRS products, the relationship between products from the two sensors varies across different locations within the Southern Alps. These differences have implications for the assimilation of data into models and the analysis of long-term trends in snow cover, especially when cloud-filling by temporal interpolation is required. Among the factors that can affect consistency, overpass time and rapidly changing targets are the represent challenges for VIIRS-MODIS calibration. Differences in cloud masking, which appears to be much stricter for VIIRS, had a significant impact and may contribute to an under-estimation of snow cover from VIIRS, relative to MODIS. Elevation, aspect, land cover and surface temperature are likely to be valuable for further examination.

UPDATE ON CLIMATE CHANGE PROJECTIONS FOR NEW ZEALAND

Christian Zammit[1], Peter B. Gibson[1], Neelesh Rampal[1], Olaf Morgenstern[1], Stephen Stuart[1], Jonny Williams[1], Hisako Shona[1], Andrew Tait[1]

[1] National Institute of Water and Atmospheric Research

Work is underway at NIWA to dynamically downscale the latest generation of global climate models (GCMs) from The Coupled Model Intercomparison Project phase 6 (CMIP6). The output from this regional climate model ensemble will significantly enhance the atmospheric model resolution of selected GCMs (typically 100-150-km) to 5-km across New Zealand. Output from the full model ensemble and detailed guidance will be made publicly available to support the first National Adaptation Plan.

The downscaling involves a 2-step procedure in which simulations from coarse-resolution GCMs are first dynamically downscaled to 12-km with the Conformal Cubic Atmospheric Model (CCAM) and then further empirically downscaled and bias-corrected to 5-km using machine learning. CCAM is a non-hydrostatic global atmospheric model which employs a stretched grid and scale-aware physics. This model configuration provides a computationally efficient approach to enhance the spatial resolution over the New Zealand domain while retaining seamless physical consistency across spatial scales.

The climate model ensemble consists of 6 GCMs driven by multiple Shared Socioeconomic Pathways (SSPs). The selection of GCM simulations to downscale has been informed through balancing: historical model performance across the region, the model equilibrium climate sensitivity, and model independence. While CCAM is the primary model employed for dynamical downscaling, for a smaller number of selected runs, comparisons were made against The Unified Model (UM, 12km) and The Weather Research and Forecasting Model (WRF, 12km). This comparison between regional climate models evaluates the historical reanalysis-driven performance as well as the regional climate change signal.

The paper aims to i) outline the main differences between the CMIP5 and CMIP6 climate ensembles, ii) provide an update on climate bias correction process, and ii) present the outcome of coupling of the raw CMIP6 climate ensemble with New Zealand Water Modelling Framework (NZWaM) over two contrasted alpine catchments in New Zealand.