SIRG 2012

Snow & Ice Research Group (NZ) Annual Workshop

13th - 15th February 2012

Lake Ruataniwha - Rowing Centre - Twizel

SCHEDULE & ABSTRACTS

Antarctica New Zealand

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NIWA Taihoro Nukurangi

UC University of Canterbury Te Whare Wānanga o Waitaha Christchurch New Zealand

Gateway Antarctica

The SIRG 2012 Annual Workshop was kindly sponsored by

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Glacier Explorers

Sir Edmund Hillary Alpine Centre

Organising Committee:

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Oliver Marsh
Wolfgang Rack
Heather Purdie
Daniel Price

Cover image: Hooker Valley & Mt.Cook; Courtesy Daniel Price

MONDAY 13th FEBRUARY 2012	
By 11:30	**ARRIVE AT TWIZEL ROWING CENTRE, LAKE RUATANIWHA, TWIZEL**
12:00 – 13:00	**LUNCH**
13:30	**WELCOME**
13:45 – 15:00	**SESSION I – SURFACE MASS BALANCE** (Chair: Tim Kerr)
13:45	*Ruzica Dadic* 'Sensitivity of Turbulent Fluxes to Wind Speed over Snow Surfaces in Different Climatic Settings'
14:00	*Jono Conway* 'Constraining the surface energy and mass balance of Brewster Glacier and its sensitivity to changes in surface climate'
14:15	*Clare Webster* 'Variation in physiographic controls on snow accumulation in the Southern Alps, New Zealand'
14:30	*Heather Purdie* 'Secondary accumulation and its impact on glacier mass balance'
14:45	*Alice Doughty* 'Glacier mass balance response to preferential snow accumulation'
15:00 – 15:30	**TEA BREAK**
15:30 – 17:05	**SESSION II – HYDROLOGY, MASS BALANCE & PERMAFROST** (Chair: Heather Purdie)
15:30	*Trevor Chinn* 'Unhinged at the snowline, - a simplified approach towards understanding AAR values'
15:45	*Wilfried Hagg* 'Estimation of future glaciations and runoff in the upper Amudarya Catchment, Tajikistan'
16:00	*David Alexander* 'Snowmelt and rain water induced glacier melting: Laboratory experiments and field observations'
16:15	*Kolja Schaller* 'Englacial water distribution at Annette Plateau: Implications for ice core recovery'
16:30	*Katrin Sattler* 'A regional permafrost distribution estimate for Canterbury's high mountain areas'
16:45	**Student Introductions** Gregor Macara, Richard Jones, Shaun Eaves

17:05	**IGS / IACS / WGMS Information** Doug MacAyeal / Andrew Mackintosh / Brian Anderson
18:00	**DINNER**
19:30	**EVENING PRESENTATION:** *Jennifer Purdie* - Meridian Energy 'Snowpack estimation and use in the Waitaki hydro electricity catchment, New Zealand'

TUESDAY 14th FEBRUARY 2012	
07:00 – 08:00	**BREAKFAST**
08:30 – 09:45	**SESSION III – ANTARCTICA I** (Chair: Pat Langhorne)
08:30	**Student Introductions** Rory Hart, Bob Noonan, Ben Thomson
08:45	*Alex Gough* 'Multiyear Sea Ice in McMurdo Sound – A case of slow compression'
09:00	*Daniel Price* 'Freeboard measurements of sea ice in McMurdo Sound, Antarctica, based on satellite altimetry and ground validation'
09:15	*Ken Hughes* 'Rate of refreezing in a bore hole in an ice shelf'
09:30	*Stefan Vogel* 'AMISOR - A decade of ice-ocean interaction and ice shelf evolution observations'
09:45	**TEA BREAK**
10:00 – 11:00	**SESSION IV - ANTARCTICA II** (Chair: Wolfgang Rack)
10:00	*Huw Horgan* 'Subglacial Lake Whillans: A Shallow Active Reservoir Beneath a West Antarctic Ice Stream'
10:15	*Oliver Marsh* ' Short-term velocity variation in outlet glaciers related to grounding zone characteristics'
10:30	*Inka Koch* 'Marine ice formation and its role in sediment entrainment at the base of the southern McMurdo Ice Shelf, Antarctica'
10:45	*Doug MacAyeal* 'Iceberg capsize as a process in ice-shelf instability: Laboratory and numerical perspective'
11:00 – 19:00	**HOOKER GLACIER & TASMAN LAKE FIELDTRIP**
20:00	**DINNER** Glentanner Restaurant

WEDNESDAY 15th FEBRUARY 2012	
07:00 – 08:00	**BREAKFAST**
08:30 – 09:45	**SESSION V – NEW ZEALAND GLACIER DYNAMICS** (Chair: Pascal Sirguey)
08:30	*Robert Dykes* 'The response of Tasman Glacier, Southern Alps, New Zealand, to the February 2011 Christchurch Earthquake'
08:45	*Todd Redpath* 'A tale of two glaciers: Contrasting behaviour of the Tasman and Murchison glaciers, 2006-2009'
09:00	*Brian Anderson* 'Retreat of lake-calving, debris-covered glaciers: hydrological implications'
09:15	*Andrew Mackintosh* 'What caused the late 20th Century advance of New Zealand glaciers?'
09:30	*Laura Kehrl* 'Glacier speed-up events on the lower Franz Josef Glacier, New Zealand'
09:45	**TEA BREAK**
10:15 – 11:15	**SESSION VI – REMOTE SENSING** (Chair: Andrew Mackintosh)
10:15	*Ekki Scheffler* 'Breathing Glacier - First Results of the Terrestrial Time-Lapse Stereo-Cameras at Franz Josef Glacier'
10:30	*Sebastián Vivero* 'Photogrammetric-derived DEMs on New Zealand glaciers: Challenges and preliminary results'
10:45	*Tim Kerr* 'New approaches to interpreting archived oblique aerial glacier photography'
11:00	*Pascal Sirguey* 'A century of ice retreat on Kilimanjaro: The mapping reloaded'
11:15	**SIRG HOUSEKEEPING**
12:00 – 13:00	**LUNCH**
13:30	**VANS DEPART FOR CHRISTCHURCH / DUNEDIN**

Sensitivity of Turbulent Fluxes to Wind Speed over Snow Surfaces in Different Climatic Settings

Ružica Dadić[1], Rebecca Mott[2], Michael Lehning[2], Marco Carenzo[3], Brian Anderson[1], Andrew Mackintosh[1]

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[2]WSL Swiss Federal Institute for Snow and Avalanche Research, SLF, Flüelastrasse 11, 7260 Davos, Switzerland
[3]Institute of Environmental Engineering, ETH Zürich, Switzerland

Local wind speed variations influence the energy and mass fluxes over snow either through snow accumulation, sublimation of drifting and blowing snow, or variations in turbulent fluxes over static snow and ice surfaces. We use idealized model experiments to analyze the sensitivity of turbulent fluxes over static snow surfaces to variations in wind speed under different climatic conditions. We find that the sensitivity increases with increasing air temperature and relative humidity. The sensitivity of turbulent fluxes is highest when the stability parameter $\zeta = 1$, which occurs at wind speed typical for glacierized catchments (3-5 ms^{-1}), and exponentially decreases either side of that range. That peak in sensitivity is caused by atmospheric stability effects, and occurs independently of the flux-profile relationships we tested. Our results quantify the significant effect of local wind speed variations on turbulent fluxes over snow and ice.

Constraining the surface energy and mass balance of Brewster Glacier and its sensitivity to changes in surface climate

Conway, J.[1], Cullen, N.J.[1], Molg, T. [2], Fitzsimons, S.J.[1], Spronken-Smith, R.[3]

[1] Department of Geography, University of Otago, Dunedin, New Zealand
[2] Institute of Ecology, Technische Universität, Berlin, Germany
[3] Higher Education Development Centre, University of Otago, Dunedin, New Zealand

Glaciers in the Southern Alps of New Zealand are seen as sensitive indicators of changing regional climate because periods of anomalous mass balance are associated with changes in the regional ocean-atmosphere system, notably the arrangement of the westerly jet stream, sea surface temperatures and surface level pressure in the New Zealand region. However our understanding of the state variables that transfer these large scale atmospheric controls to mass balance through altered glacier surface energy balance are still not well developed, limiting our ability to understand the atmospheric significance of previous glacier extent and to confidently predict future changes in these systems. The Brewster Glacier, situated in the central Southern Alps, now has the longest mass balance record in New Zealand, accompanied by a periodic meteorological record. A high quality one-year record of surface climate has been obtained over the glacier surface along with a record of daily mass balance through both the ablation and accumulation seasons. This presents a unique opportunity to constrain the contribution each component of the surface energy balance makes to glacier mass balance at daily, monthly and seasonal timescales. In addition the sensitivity of the energy and mass balance to changes in surface layer atmospheric state variables is explored, allowing for a more robust understanding of the surface boundary layer controls on the surface energy and mass balance of a glacier surface in the Southern Alps.

VARIATION IN PHYSIOGRAPHIC CONTROLS ON SNOW ACCUMULATION IN THE SOUTHERN ALPS, NEW ZEALAND

Webster, C.S[1], Kerr, T.R[2], Kingston, D.G[1]

[1]Department of Geography, University of Otago, Dunedin
[2]National Institute of Water and Atmospheric Research, Christchurch

Snow depth and water equivalent in alpine regions show high spatial variability that is influenced by a number of different processes and their interaction. Manual snow depth surveys conducted in the upper Jollie Catchment at the onset of the snowmelt season between 2007 and 2010 have provided an opportunity for investigating the spatial and inter-annual variability in snow mass near the peak of the snow accumulation period. Indices describing the physiographic controls on snow accumulation were extracted from a digital elevation model of the Jollie Catchment. These indices were elevation, slope, aspect, total incoming solar radiation and local wind exposure/sheltering. Binary regression tree analysis shows a change in the controlling physiographic variables and their interactions between the study years. The substantial role that elevation plays in 2007 (accounting for almost 90% of the explained variance in the data set) compared to 2010 (accounting for less than 30% of the explained variance) can be attributed to the frequency and duration of troughing episodes over the country. In addition, longer troughing sequences (up to two weeks) result in greater accumulation at the end of the season compared to more frequent, shorter sequences (one or two days). In addition, a comparison of total SWE values calculated using the binary regression tree models and a TopNet model using local precipitation and temperature data has identified the important role of physiographic variables other than elevation in controlling snow distribution.

Secondary accumulation and its impact on glacier mass balance

Purdie, H.[1], Lawson, W.[1], Owens, I.[1], Kerr, T.[2,] Hewitt, K.[3]

[1]Department of Geography, University of Canterbury
[2]National Institute of Water and Atmospheric Science, Christchurch
[3] Cold regions Research Centre, Wilfrid University, Ontario

Glacier mass balance models often consider accumulation solely in terms of direct precipitation input, but on some glaciers, avalanche and wind transport can make considerable contribution to the overall snow accumulation. Improved understanding of these secondary accumulation processes is desirable in order to refine mass balance modes and better interpret glacier response to climate in the past, present and future. In glaciology it is relatively commonplace to use parameters like the snowline, equilibrium line and the accumulation area ratio to estimate the potential equilibrium (or disequilibrium) of a glacier, and previous glacier extent is utilised to estimate potential changes in temperature and precipitation. However on glaciers with complex accumulation processes, these traditional climate indicators lose some validity. The concept of 'intensification of glacier nourishment' has been used by Hewitt (2011) to explain enhanced snow accumulation on Karakoram glaciers associated with avalanche transport, while Dethier and Frederick (1981) attributed up 30% of accumulation on a Washington glacier to the combined processes of wind and avalanche transport. Observations in New Zealand indicate that some of our glaciers, in particular the smaller ones, for example Cameron Glacier (Doughty et al., this volume), may survive because they receive substantial secondary accumulation. However, until we better understand the role that wind and avalanche transport has to overall glacier mass balance, it will be difficult to determine the fate of such glaciers with ongoing climate change. In this paper we suggest that it may be possible to learn more about the role of varying accumulation processes to glacier mass balance by employing a variety of methods: 1. Identify and map spatial and topographical characteristics in the New Zealand Southern Alps that increase the likelihood of a glacier receiving significant snow input from wind and/or avalanche transport. 2. Use snow crystal morphology, density, water isotopes and Ground Penetrating Radar to quantify the proportion of accumulation attributable to the different accumulation processes, namely precipitation, wind and avalanche. 3. Compare point surface energy balances from areas subject to secondary accumulation to assess the impact this has to overall glacier mass balance and 4. Determine if a mass balance model with wind and gravitational transport modules can simulate snow contribution from these varying accumulation processes on a selection of glaciers in the Southern Alps. The improved process based understanding we hope to gain by studying accumulation regimes on New Zealand glaciers will be applicable to other international mass balance studies in mountainous terrain.

Dethier, D.P. and Frederick, J.E. 1981: Mass balance of "Vesper" glacier, Washington, U.S.A. *Journal of Glaciology* **27**, 271-282.

Hewitt, K. 2011: Glacier change, concentration, and elevation effects in the Karakoram Himalaya, Upper Indus Basin. *Mountain Research and Development* **31**, 188-200.

GLACIER MASS BALANCE RESPONSE TO PREFERENTIAL SNOW ACCUMULATION

Doughty, A.M.[1], Mackintosh, A.N.[1], Anderson, B.M.[1], Kerr, T.R.[2], Dadic, R.[1], Kees, L.J.[3], Horgan, H.J.[1], Chinn, T.J.H.[4]

[1]Victoria University of Wellington, Wellington
[2]NIWA, Christchurch
[3]Hawke's Bay Regional Council, Napier
[4]Lake Hawea Institute of Cryodynamics, LGM Hawea, RD2 Wanaka

Gravitational mass transport and deposition (MTD) of snow occurs frequently in the steep and complex terrain of the Southern Alps of New Zealand. Accumulation of this redistributed snow in névés directly contributes to glacier mass input, and potentially increases the albedo where snow is deposited and decreases albedo where bedrock is exposed, affecting the glacier energy balance. We investigate the response in mass balance of Cameron Glacier, located in the Arrowsmith Range of western Canterbury, to the presence/absence of redistributed snow as simulated with an EBM which includes a MTD component. The energy balance model simulated one year (April 2009 to March 2010) and the modelled snow depth was compared to snow thickness data from a Ground Penetrating Radar survey taken in December 2009. The modelled glacier mass balance with the MTD model shows a similar pattern to measured data, whereas, without the MTD model, the mass balance model fails to reproduce the correct snow distribution or thickness. It is important to capture such processes in energy balance models to predict how these types of glaciers could respond to climate change.

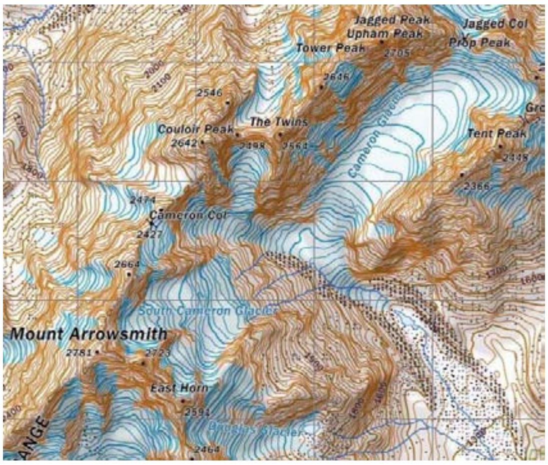

Fig. 1 (above) – Topographic map of Cameron Glacier, showing elevation contours.

Fig. 2 (right) - Photograph of the Cameron Glacier in the Arrowsmith Range. The glacier surface elevation increases toward the upper right side background, with the terminus in the lower foreground. Notice the equilibrium line altitude traces up the centre of the glacier (dotted line), due, in part, to MTD processes from the Twins and Tower peaks. Photo taken by A. Willsman during the end of summer snowline survey (5 March 2010).

NOTES

Unhinged at the snowline, - a simplified approach towards understanding AAR values.

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[2]Antarctic Research Centre, Victoria University of Wellington, PO Box 600, Wellington.

This study is founded on the availability of a unique dataset collected from the near 50 ‘index’ glaciers distributed throughout the New Zealand Southern Alps, now with 34 years of observations. By very good fortune the observations have coincided with an unusual climatic period of positive mass balances that have provided the means to derive the steady-state accumulation area ratio (AAR) values for each glacier. Thus empirical assessments may be made on the relationship between glacier shape and its AAR value, the ratio found by dividing accumulation area by the area of the entire glacier (Meier and Post, 1962). This study approaches the AAR problem from the notion that; (1) it is the equilibrium line altitude (ELA) that determines the existence and size of a glacier on a mountain; and (2) it is the topography that determines the glacier shape. For a given glacier in a given climate, the ELA is fixed while the AAR value will be dependent on the glacier morphology resulting from the glacier fitting its mass balance and ice discharge into the topography. This shape delivers the ice discharge from the accumulation area, through the ELA to replace losses in the ablation zone. However, although ice discharge rates are basically governed by the mass balance gradient (the glacier activity index of Meier and Post (1962)) comparison of low precipitation (polar) and high precipitation (wet temperate) glaciers suggest that there is no trend in the AAR values related to the amount of precipitation. The study has derived its basic AAR values from the analyses of simple geometric shapes rather than the common cirque-shaped glaciers which are the product of a long period of Pleistocene glacial erosion and whose AAR values have followed the changing climate and landscape.

Meier, M. F., and A. S. Post (1962), Recent variations in mass net budgets of glaciers in western North America, *IASH*, *58*, 63-77.

ESTIMATION OF FUTURE GLACIATION AND RUNOFF IN THE UPPER AMU-DARYA CATCHMENT, TAJIKISTAN

Hagg, W.[1], Hoelzle, M.[2], Wagner, S[3].

[1]Department of Geography, Ludwig-Maximilians-University, Munich, Germany
[2]Department of Geosciences, University of Fribourg, Fribourg, Switzerland
[3]ITos-GmbH, Ebnat-Kappel, Switzerland

A conceptual hydrological model was set up in the upper catchment of the Amu-Darya, the major tributary to the Aral Sea in the past. Driven by daily temperature and precipitation, the model reproduced hydrographs in a very satisfactory way. Based on two glacier inventories from the mid-20st century (WGI, World Glacier Inventory) and from 2003 (GLIMS, Global Land Ice Measurements from Space), a simple parameterization scheme based on steady state conditions was applied to infer the ice volumes and glacier areas for the two different time periods in the past. Assuming temperature rises of 2.2°C and 3.1°C, which mark the extreme values of regional climate scenarios, the same method was used to extrapolate glaciation to the year 2050. The results show that these temperature rises will reduce the current glacier extent of 431 km² by 36% and 45%, respectively. To assess future changes in water availability, the hydrological model input was modified according to the regional climate scenarios and the resulting glacier changes. The runoff scenarios reveal no changes in annual runoff, because the glacier area decrease is balanced out by enhanced melt rates. However, there is an important seasonal shift of water resources from summer to spring, unfavorably affecting agriculture and irrigation in the lowlands. In August, runoff will be reduced by 25-30%.

SNOWMELT AND RAIN WATER INDUCED GLACIER MELTING: LABORATORY EXPERIMENTS AND FIELD OBSERVATIONS

Alexander, D.J.[1], Shulmeister, J.[1], Davies T.R.H.[2] and Callow, N.J.[1]

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[2]Department of Geological Sciences, University of Canterbury, Christchurch, New Zealand

Rainfall heat flux is used in the calculation of the surface energy balance for glaciers, but this term ignores other melting processes occurring within glaciers that may be caused by advection of heat from rainfall, as well as melting caused by snowmelt-sourced water and runoff water entering a glacier via streams from its ice-free catchment area. We investigate these using laboratory experiments on cooling rates of rain as it falls on ice, as well as field observations from the Franz Josef Glacier, New Zealand on supraglacial and proglacial stream temperatures and waterfall temperatures. Surface rainfall heat flux calculations indicate melting at the terminus of this glacier is ~0.6 m water equivalent (w. eq.) yr^{-1} (2–3% of total melt), with only an additional ~0.05 m w. eq. yr^{-1} produced by heat advection within the glacier. Supraglacial water temperature measurements of 0–0.2°C compared with proglacial water temperature measurements of 0.7–1°C indicate additional and unknown heat sources within the glacier. We interpret these heat sources and warmer temperatures as a result of high volumes of warm water (3–8°C) entering the glacier as terrestrial streams, not all of whose heat energy is expended in melting ice, which yields melt at the terminus of 1.2–1.8 m w. eq. yr^{-1}. Thus, the rainfall heat flux on the surface of glaciers may not accurately reflect the full melting potential as a result of precipitation and this is important when considering energy or mass-balance of non-polar glaciers.

ENGLACIAL WATER DISTRIBUTION AT ANNETTE PLATEAU: IMPLICATIONS FOR ICE CORE RECOVERY

Schaller, K.L.A.[1], Anderson, B.M.[1], Morgenstern, U.[2], Mackintosh, A.[1]

[1]Victoria University Wellington, [2]Geological & Nuclear Sciences

Annette Plateau is a potential site for ice core retrieval to gain a climate record from New Zealand ice. It is a low angle glacier roughly 140 m deep, 1km long and 500 m wide, located at 2220 m a.s.l on the Sealy Range in Aoraki/Mt Cook National Park. In 2009 an ice core was drilled at Annette plateau, but drilling stopped at a depth of 44.5 m due to the interception of water within the glacier, which flooded the drill hole. This study uses ground penetrating radar, a technique used in the past to look at englacial structures, ice flow, water within glaciers and to identify ice depth for a coring site. Ground penetrating radar (GPR) is used to image sub-surface profiles across the glacier to gain an understanding of the glaciers hydrological system and locate potential sites for ice core retrieval. This study aims to create a map showing the distribution of water and structures within the glacier and to indicate the degree to which ice cores form South Island glaciers are adversely affected by meltwater. Data are collected with the GPR using 100 MHz antennae in transects at 20 m intervals across the upper 400 m of the glacier. Profiles are also completed over the ice-coring site, which will be correlated with the ice core stratigraphy to help interpretation of the GPR data.

A REGIONAL PERMAFROST DISTRIBUTION ESTIMATE FOR CANTERBURY'S HIGH-MOUNTAIN AREAS

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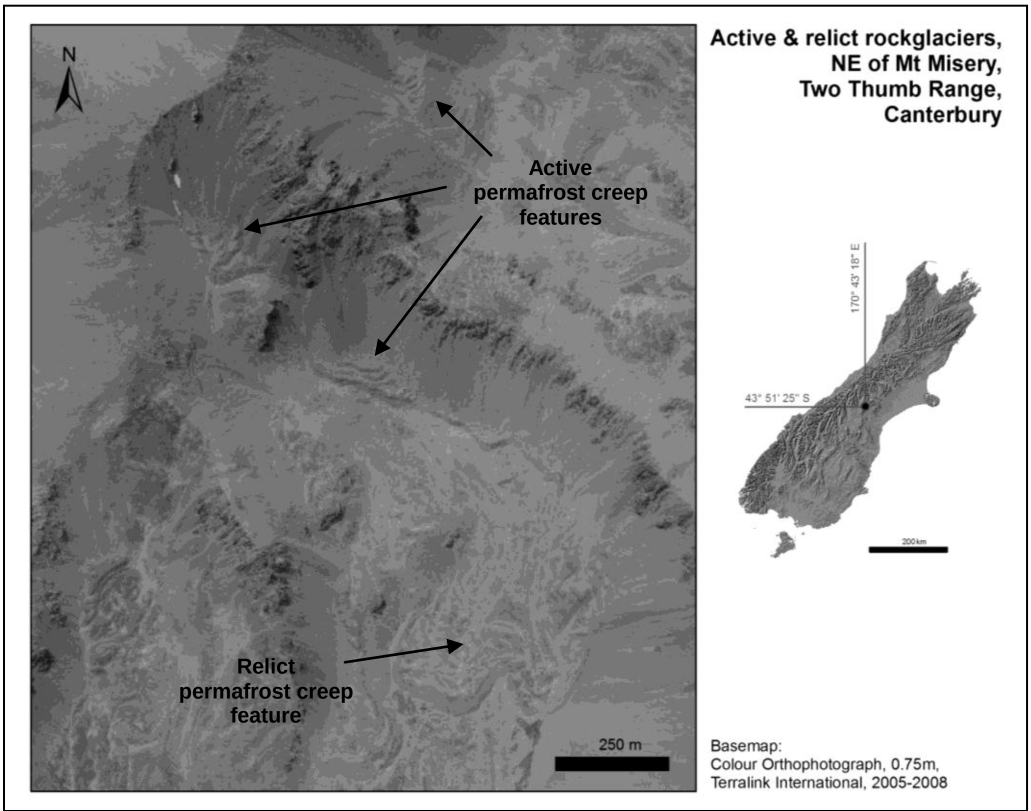
School of Geography, Environment and Earth Sciences
Victoria University of Wellington, New Zealand

With many South Island summits rising above 2000 m a.s.l. and extensive areas experiencing mean air temperatures at or below 0˚C for several months a year, occurrences of discontinuous alpine permafrost can be expected in the Southern Alps of New Zealand. Numerous intact rockglaciers and perennial snow patches are visible indicators of the existence of this thermal subsurface phenomenon. However, research on the geographic extent of permafrost has been rudimentary to date, and existing estimates are restricted to only a few locations or single mountain ranges.

In this talk we present the results of a first regional permafrost estimate for the high-mountain areas of the Canterbury District. Potential lower limits of contemporary permafrost distribution were calculated by means of logistic regression, using an inventory of active and relict rockglaciers as dependent and mean annual air temperature and potential incoming solar radiation in snowfree months as independent variable inputs. Results are compared to existing permafrost distribution estimates as well as long-term surface temperature data sets, recorded by miniature data loggers at several locations in the Irishman Stream Valley, Ben Ohau Range, in order to assess the quality of the model outcome.

This regional-scale estimate of permafrost extent will be compared to the distribution of past and recent debris flow events to assess the potential influence of permafrost degradation on debris flow activity.



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Multiyear Sea Ice in McMurdo Sound – A case of slow compression

Gough, A. J.[1], Mahoney, A. M.[1,2], Langhorne, P. J. [1], Williams, M. J. M.[3], Haskell, T. G. [4]

[1]University of Otago
[2]University of Alaska, Fairbanks
[3]National Institute for Water and Atmospheric Research Ltd.
[4]Industrial Research Ltd.

Multi-year sea ice covered the southern portions of McMurdo sound from 1998 to 2011, a situation that was somewhat unusual in the short history of human occupation. A number of roads, routes and field camps utilise the multi- and first-year sea ice, probably making it the most trafficked sea ice in Antarctica. Strong fluxes of heat during the summer melt away the previous winter's growth, and heavy snow accumulation depresses the sea ice freeboard allowing seawater to flood the sea ice in summer, which eventually freezes as snow-ice. After a number of years the majority of the ice thickness is composed of frozen flooded snow. We were able to profile the thickness variations of an area of ten year old sea ice under compression from the nearby McMurdo Ice Shelf. We investigate the bulk mechanical properties of snow-ice and put limits on the accumulated strain imposed by the nearby ice shelf. We also provide a time-series of minimum fast-ice extent in McMurdo Sound for the years 2003 to 2011.

FREEBOARD MEASUREMENTS OF SEA ICE IN MCMURDO SOUND, ANTARCTICA, BASED ON SATELLITE ALTIMETRY AND GROUND VALIDATION

Price, D.[1], Rack, W.[1], Langhorne, P.[2], Haas, C.[3]

[1]Gateway Antarctica, University of Canterbury
[2]Department of Physics, University of Otago
[3]Department of Earth & Atmospheric Sciences, University of Alberta

The Southern Ocean and Antarctic coastline remain unexplored in terms of the collation of large data sets on sea ice characteristics. A slight overall increase in areal extent of Antarctic sea ice has been documented, however with significant regional differences. A 5% loss in the Amundsen Sea is almost exactly balanced by an increase in the Ross Sea. A major unknown is the thickness of sea ice in the Southern Ocean, which is needed to understand the volume flux of ice and to better quantify its role in the global climate system. In this study we investigate the potential of satellite based observations for mapping the spatial characteristics and freeboard heights of sea ice in the McMurdo Sound area. McMurdo Sound sea ice conditions are comparable to that of large sections of the Antarctic coastline as the area is under the influence of an ice shelf. The area is also of much interest due to dynamic changes during the last decade or so. McMurdo Sound also provides ease of access from nearby Scott Base and McMurdo Station for ground-truthing measurements. Freeboard, the segment of sea ice which protrudes above the water surface is detectable via altimeter methods from space. With the addition of other information this allows indirect estimation of thickness. This information will be collected in the field during the 2011/2012 and 2012/2013 Antarctic summer field seasons and includes snow depth and density measurements, ice drill holes, surface-borne electromagnetic (EM) induction devices and radar. Furthermore, an extensive Helicopter-borne EM campaign was carried out greatly increasing the ground-truthed area in the region. The data set is also supported by a similar Helicopter survey which was carried out in 2009. Further data presented stem from NASA's ICESat laser altimeter and the European Space Agency's Envisat and CryoSat-2 Synthetic Aperture Radars. Ground validation is crucial for accurate determination of freeboard and subsequent estimation of thickness with regards to CryoSat-2 as the penetration of the radar altimeter into snow cover is variable. Of primary importance is the identification of a sea surface reference level from which freeboard can be referenced. Over limited spatial and temporal scales this is a simple procedure. However, due to variations in the sea surface height from a changing geoid, tidal cycles and atmospheric pressure, the reference surface cannot be assumed and has to be re-calculated over the study area. Fieldwork measurements correlate well with the generalised impression of sea ice conditions so far produced from the satellite altimetry and imagery. Methods are currently under development. Presented here are freeboard estimates from the period 2003-2011. Ultimately envisaged is the development of sea ice thickness maps and a better understanding of sea ice processes in the western Ross Sea.

RATE OF REFREEZING IN A BORE HOLE IN AN ICE SHELF

Hughes, K. G.[1], Langhorne, P. J. [1], Williams, M. J. M.[2]

[1]University of Otago
[2]National Institute of Water and Atmospheric Research

Two mathematical models based on the conservation of either salt or heat are created to simulate the closure of a bore hole formed by hot water drilling in the Ross Ice Shelf, Antarctica. The heat flux model uses a numerical solution to the heat conduction to model the evolution of the temperature distribution in the host ice. Ice growth is consequently calculated from the balance of this sensible heat and the latent heat released at the growing ice/water interface. The salinity variation model uses experimental data to find radius change from the salt budget in the bore hole assuming a closed system. The heat flux model broadly confirms predictions of the refreezing rates derived by the conservation of salt which is based on observation. This gives confidence in the generalisation of the heat flux model for predicting the rates of closure of other bore holes.

The predictions from both are subject to a large uncertainty due to the poorly defined value of the solid fraction of ice that refreezes, per unit volume of seawater, on the side of the bore hole. This is taken to be 0.4 throughout this study. The predicted rates are also strongly dependent on the initial conditions and the boundary conditions chosen but typical results show the diameter decreases by about 5 - 10 mm hr^{-1}.

AMISOR A DECADE OF ICE-OCEAN INTERACTION AND ICE SHELF EVOLUTION OBSERVATIONS

Vogel, S.W[1,2], Craven, M.[1,2], Allison, I.[1], Galton-Fenzi, B.K.[1], Herraiz-Borreguero, L.[1], Hunter, J.R.[1], Treverrow, A.[1], Warner, R.C.[1,2], Williams, M.J.M.[3]

[1]Antarctic Climate and Ecosystems Cooperative Research Centre, Hobart, Tasmania, AUSTRALIA
[2]Australian Antarctic Division, Dep. of Sustainability, Environment Water Population and Communities, Kingston, Tasmania, Australia
[3]National Institute of Water & Atmospheric Research, Wellington, New Zealand

Over the past decade, the multi disciplinary AMISOR (Amery Ice Shelf - Ocean Research) Project has studied ice-ocean interaction and ice dynamic processes. The project accessed the sub ice shelf cavity through six hot water-drilled borehole locations deploying oceanographic instrumentation, recovering ice cores and observing biological activity. The ongoing project provides one of the longest time series of ocean properties beneath an ice shelf providing insight into distribution and seasonality of melt/freeze processes, the nature of marine accretion ice and seasonality of sub ice ocean circulation. Aside from valuable insight into sub-ice-shelf oceanographic processes the data also provides valuable insight into glaciological processes and ice shelf dynamics and evolution.
Here we present an overview on previous AMISOR work and review the oceanographic data from a glaciological and ice shelf evolution/stability perspective. We for example are currently using CTD pressure data to decipher short and long-term changes in ice shelf mass balance. Also over the course of our observations, at two of the six field site locations, instrumentation close to the ice-water interface has frozen into the ice shelf, providing unique insight into the accretion of marine ice to the ice shelf and the interconnectiveness between the marine accretion ice and the sub ice shelf cavity. We will also provide an overview on plans to continue the AMISOR sub ice shelf oceanography work over the next 5 years as well as expanding the work to an integrated glaciology oriented ice shelf mass balance study.

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Subglacial Lake Whillans:
A Shallow Active Reservoir Beneath a West Antarctic Ice Stream

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Active subglacial lakes concentrate the distribution of water beneath ice sheets in both space and time. Here we report on ground-based geophysical observations from Subglacial Lake Whillans (SLW), which lies beneath Whillans Ice Stream in West Antarctica. Seismic and surface observations from SLW reveal that this active lake forms a persistent, albeit fluctuating, reservoir beneath the ice stream. Imaging and phase observations from active-source seismic data show that SLW, which was in a low-stand state when surveyed, is a perpetually shallow feature, with a low-stand water column of less than 8 m depth imaged along 5 km of the 45 km profiled, and high-stand only a few meters more. This water column presents a suitable drill site at S 84.240°, W 153.694°. The water column is located within the lake's hydropotential low, which is independently determined using densely spaced radar and GPS observations. The water column also lies within the region of maximum observed ICESat elevation range. Elsewhere, the majority of the bed appears wet with water thicknesses below the imaging resolution of our data (< 5 m). The surface expression of the actively filling and draining lake, previously revealed by ICESat elevation data and image differencing, generally corresponds to the seismic estimate of water extent, with notable exceptions occurring at the upstream and downstream ends of the lake. These exceptions indicate that SLW: (1) grounds, or has negligible water, in places at low-stands that are within the lake at high-stand, or, (2) has disconnected or transient active and inactive portion.

SHORT-TERM VELOCITY VARIATION IN OUTLET GLACIERS RELATED TO GROUNDING ZONE CHARACTERISTICS

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High precision GNSS measurements across grounding zones around Antarctica show non-linear velocity variations in glacier flow in response to ocean tides. These periodic fluctuations occur at timescales of hours, days, weeks and longer and have been linked to tide induced changes in basal stress for some of the fast flowing ice streams in West Antarctica. Here we present similar observations of diurnal and fortnightly variations in velocity for laterally-confined East Antarctic outlet glaciers which drain into the Ross Ice Shelf, through the Transantarctic Mountains.

We discuss past, current and future work on these short term velocity variations and how they are linked to both basal stress and different period solar and lunar tides. With this in mind, an overview of the limits of the satellite techniques, notably InSAR, for velocity mapping in the grounding zone due to these tides is also presented. GPS measurements from the Beardmore Glacier obtained in 2010-11 are compared with published data from the Rutford Ice Stream (Gudmundsson, 2006; King et al., 2010) and discussed in relation to as yet unprocessed data collected on the Skelton Glacier in 2011-12. Strongly different signals are observed where semi-diurnal tides dominate to where diurnal tides are common. The presence of overwhelmingly diurnal tides along the western Ross Ice Shelf provides a unique opportunity to study the effect of grounding line configuration on glacier response for these fast-flowing outlet glaciers.

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MARINE ICE FORMATION AND ITS ROLE IN SEDIMENT ENTRAINMENT AT THE BASE OF THE SOUTHERN MCMURDO ICE SHELF, ANTARCTICA

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This study aims to understand processes of basal ice shelf ice (marine ice) formation and sediment entrainment into this ice at the Southern McMurdo Ice Shelf (SMIS), Antarctica. At its southern margin, this small (~5000 km^2) ice shelf flows toward shore at a rate of 1-3km/yr and is actively forming moraines. Basal marine ice can be easily accessed from the ice shelf surface due to an upward movement of basal ice shelf layers resulting from a negative surface mass balance of SMIS in the south. During the summer seasons of 2007 and 2010 four ~3m-long ice cores and one ~10m-long ice core were recovered from the bare ice zone of southern SMIS. Two additional ice cores further away from shore where the ice shelf is snow covered were also recovered. Additionally three ice blocks were extracted from within the ice-cored moraines to compare moraine ice properties with the ice shelf ice. The ice and moraine samples were analyzed in 8-10 cm long sections downcore for their crystallography (optical c-axis orientation, size and shape of ice crystals) and chemistry (major ions and water isotopes). Ice in the bare ice zone close to shore clearly shows a crystallography with deformed frazil ice crystals typical for marine ice and equigranular crystals typical for glacial ice for ice core extracted in the snow covered area further away from shore. This is confirmed by the higher salinities and less depleted water isotope ratios for the marine ice and the opposite chemical signature for meteoric ice. Ice crystals in the moraine ice indicate mechanical deformation and grain growth. The moraine ice is on average isotopically heavier and less saline than marine ice but isotopically lighter and more saline than the meteoric ice possibly indicating a mixed-origin. Results from this study will help to contribute to the understanding of ice shelf moraine formation whilst improving the knowledge on marine ice formation and deformation. Little is known about this type of ice which is thought to play an important role in stabilizing ice shelves due to its stronger mechanical properties than meteoric ice.

ICEBERG CAPSIZE AS A PROCESS IN ICE-SHELF INSTABILITY: LABORATORY AND NUMERICAL PERSPECTIVES

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Observations of the post-collapse “death assemblage” (arrangement of icebergs) of the various Antarctic Peninsula ice shelves show that a large fraction, possibly a majority, of ice-shelf fragments (icebergs) no longer retain the “snow side up” configuration—they have capsized. A hemisphere away, in the fjords of Greenland where outlet glaciers discharge their ice into the ocean, iceberg calving is also accompanied by almost immediate iceberg capsize, and this appears to be an extraordinary violent process that drives the dense ocean surface cover of ice mélange down the fjord. I shall review laboratory scale experiments on iceberg capsize dynamics (using a water tank and plastic icebergs that have the appropriate density) as well as numerical experiments designed to illuminate the role of iceberg capsize as an energy source for ice-shelf disintegration and outlet-glacier fjord dynamics. Of particular interest, but without a pre-conceived answer, will be the question of whether iceberg capsize dynamics has an effect on glaciers that terminate in proglacial lakes, such as the Tasman Glacier of New Zealand.

NOTES

THE RESPONSE OF TASMAN GLACIER, SOUTHERN ALPS, NEW ZEALAND, TO THE FEBRUARY 2011 CHRISTCHURCH EARTHQUAKE

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Glacier retreat resulting from iceberg calving represents one of the major controls on ice loss from water-terminating glaciers (ice sheets, tidewater and freshwater glaciers) globally. However, the impact that calving has on the transfer of mass between the cryosphere and hydrosphere is still heavily debated, and the physical mechanisms behind calving remain poorly understood. Hitherto, the initiation of calving events has largely been attributed to underlying glaciological mechanisms (including fracturing of ice due to high longitudinal stress gradients) and changes in the proglacial water-body characteristics. We present evidence for a large-magnitude calving event following high (>M_w 6) magnitude earthquake as a potentially important triggering mechanism of calving in tectonically active areas. We describe the response of Tasman Glacier, New Zealand, a freshwater-terminating glacier undergoing accelerated calving retreat, to the M_w 6.3, 5.7 and 4.5 Christchurch 22 February 2011 earthquakes and the subsequent calving event. Time-series analysis of timed video and photo records of the glacier front immediately before, during, and after the 22 February earthquakes demonstrate that the large calving event on the 22 February 2011 occurred in direct response to a resonance effect caused by shear (S-) waves oscillating the terminus at the ice-water interface. We suggest that, in this instance, the magnitude of calving was amplified because Tasman Glacier had reached a critical threshold for buoyancy-induced calving in relation to perturbations in lake level. Prior to this event, small- to moderate magnitude calving, leading to the retreat of Tasman Glacier, had been dominated by waterline melt at the terminus destabilising the subaerial ice cliff, with recent (post 2006) large calving events primarily driven by torque-induced-buoyancy driven calving. Our study illustrates that in tectonically active areas coseismic-initiated calving can have a periodic effect on retreat, potentially destabilising a glacier system leading to accelerated retreat.

A TALE OF TWO GLACIERS: CONTRASTING BEHAVIOUR OF THE TASMAN AND MURCHISON GLACIERS, 2006 – 2009

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An eleven year (2000 – 2011) velocity record, derived by cross-correlation of ASTER imagery, now exists for the Tasman Glacier. The methodology used for producing this velocity record has been optimised and validated with data from repeat DGPS surveys on the glacier surface, justifying its extension to other similar (i.e. large, debris covered) valley glaciers in the Southern Alps. Subsequently, four annually acquired images were used to produce three flow-fields for the Murchison Glacier for the 2006 – 2009 period. A rigorous sub-pixel level accuracy assessment accompanied flow-field derivation, facilitating detection of significant temporal variability in flow velocities. Small, steep tributary glaciers (Baker, Dixon and Mannering), originating in the Malte Brun Range, dominated the flow regime of the Murchison Glacier with flow velocities exceeding 200 m a^{-1}. Beyond these tributaries, the main trunk of the Murchison Glacier was found to be slow-flowing. Between 2006 and 2007, significant flow acceleration occurred on the Mannering Glacier. Deceleration occurred on the Baker, Mannering and parts of the Murchison between 2007 and 2008. Over the same time period, widespread deceleration was observed on the Tasman Glacier between 2006 and 2007, followed by acceleration between 2007 and 2008. The Murchison Glacier appears to be at a more advanced stage of decay than the Tasman, with most active flow confined to its tributaries. That the observed velocity changes are not synchronous between the Tasman and Murchison glaciers suggests that the mechanisms driving temporal variability in flow, or the forcings behind those mechanisms, differ between the two glaciers.

Retreat of lake-calving, debris-covered glaciers: hydrological implications

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Climatic warming expected in the next decades will have a significant impact on New Zealand glaciers, and runoff in glacierised catchments. However, predicting the retreat of debris-covered and lake-calving glaciers is not straightforward. In order to improve our understanding of glacier retreat and hydrological impacts, we apply a glacier model which takes into account surface energy balance, ice flow, debris cover and lake-calving to the Hooker and Mueller catchments. The bed of these glaciers is largely unknown, except near the terminus, so a mass-flux based calculation of glacier thickness is carried out. Because of the long response times of these glaciers, the model is initialised at the ~1860 ice extent. A warming consistent with the instrumental record is then applied up until 2000. As expected, the model simulates the downwasting of these glaciers up until ~1980, when the model glacier geometry allows the start of lake development. From 2000-2100, changes to temperature and precipitation are applied from downscaled climate change scenarios. The resulting response of the glacier and the evolution of the pro-glacial lake is dependent on the exact model structure and boundary conditions used. The following generalisations can be made: (a) a substantial amount of debris-covered ice will persist until 2100 and probably for many decades beyond, and (b) under high warming scenarios these debris-covered ice masses will become disconnected from ice fed from the remaining high-elevation accumulation areas (c), because of this persistence of debris-covered ice, glaciers continue to contribute to runoff for longer (beyond 2100) than would otherwise be expected.

WHAT CAUSED THE LATE 20th CENTURY ADVANCE OF NEW ZEALAND GLACIERS?

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Mountain glaciers on Earth have retreated dramatically during the last century in response to a ~0.6 K warming, and more than 90% are presently in retreat. Although few attribution studies have been made, widespread loss of glacier ice is consistent with the consequences of anthropogenic global warming. Advancing glaciers are an anomaly and of interest to scientists and wider society. Of those glaciers that have advanced in the last few decades, the majority experienced non-climatic surge or tidewater/lake-calving cycles. A smaller number of glaciers have advanced in response to climate. Out of 442 glaciers examined by the World Glacier Monitoring Service in 2005, 26 were advancing, 18 were stationary and 398 were retreating. Of the 26 advancing glaciers, 15 were located in New Zealand. We apply an energy balance model driven by gridded climate datasets to glaciers in the central Southern Alps of New Zealand, and we demonstrate that positive glacier mass balance and ultimately the advance of several glacier fronts between 1980 and ~2005 resulted from regional-scale cooling events in the 1980s and 1990s. In particular, cooling during the prominent 1983 and 1997 El Nino events was important in causing subsequent glacier advances. A concurrent precipitation increase in the 1990s was not primarily responsible, as reported in IPCC AR4. Our results indicate that natural climate variability can result in departures in the overall trend of glacier retreat, especially in maritime regions where glaciers are sensitive to forcing, and where the coupled ocean-atmosphere system exhibits significant inter-annual variability.

Glacier speed-up events on the lower Franz Josef Glacier, New Zealand

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Glacier speed-up events occur when the subglacial drainage system cannot accommodate a given water input to the system, and the subglacial water pressure increases. The contribution of these events to overall glacier motion is still poorly understood. Several studies (Van de Wal and others 2008; Sundal and others 2011) have suggested that high ice flow velocities during speed-up events are offset by lower ice flow velocities due to a more efficient subglacial drainage system after the event. In this study, we combine in-situ velocity measurements with a full Stokes glacier flowline model to understand the spatial and temporal variations in glacier flow on the lower Franz Josef Glacier. This glacier experience significant water inputs throughout the year (Anderson 2006), and as a result, we would expect an efficient subglacial drainage system at the Franz Josef Glacier. In March 2011, measured ice flow velocities increased by up to 75% above background values in response to diurnal melt cycles and rain events. These speed-up events occurred at all survey locations across the lower glacier. Through flowline modelling, we show that the enhanced glacier flow can be explained by a spatially-uniform subglacial water pressure that increased during periods of heavy rain and glacier melt. We suggest from our results that the variability in water inputs, rather than in the mean value, is the primary driver in glacier speed-up events (cf. Schoof 2010). If this is the case, then glacier speed-up events should continue into the future, even after a glacier's drainage system becomes well-developed. Future studies should focus on determining the contribution of glacier speed-up events to overall glacier motion and their impact on glacier mass balance and future sea level rise.

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NOTES

Breathing Glacier - First Results of the Terrestrial Time-Lapse Stereo-Cameras at Franz Josef Glacier

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In glaciology, satellite remote sensing has been very successful in capturing snapshots of surface properties and elevation, as well as average ice dynamics between image acquisitions. However, the temporal resolution to monitor glaciers is primarily restricted by the repeat pass interval of the satellites, but also cloud coverage, imaging geometry, and pixel resolution. SAR interferometry is the only satellite technology which captures ice dynamics over very short intervals at high resolution, but the application is quite limited at valley glaciers in temperate climate. In glaciological studies often a continuous observation is required.

In March 2011, we installed two time-lapse cameras on Champness Rock about 200m above the terminus of Franz Josef Glacier. The cameras were separated by about 25 m to capture stereo pictures of the glacier surface at regular 15 minute intervals. The goal was to obtain a series of (i) Digital Elevation Models, and (ii) ice velocity fields, in order to quantify variations in surface elevation and ice dynamics over a period of about 7 months. For the set-up we used a commercial SLR time-lapse camera package. Because of the imaging geometry, we focused in our analysis on the glacier area at a distance between about 0.5 and 2 km from the camera position. In this area near simultaneous ground validation measurements are available. The pixel resolution at this range varies from about 0.2 to 0.6 m/pixel.

The generation of DEMs of selected image pairs and orthorectification of pictures into UTM projection has been achieved. The working steps include camera calibration, identification of ground control points, and the generation of look up tables associating corresponding pixels between camera and map geometry. Two elevation models have been analysed in more detail. They reveal an average surface lowering of 3 to 14 cm/d between March and May, with the lower values at the medial moraine and the higher values towards the glacier margin. The velocity field shows significant variations in space and time, but the analysis was not finished by the time of writing the abstract.

In this presentation we will discuss the technical and environmental challenges for the camera set-up, the data analysis along with first results, as well as lessons we have learnt so far for the installation of (stereo) time-lapse cameras for monitoring New Zealand glaciers.

PHOTOGRAMMETRIC-DERIVED DEMs ON NEW ZEALAND GLACIERS: CHALLENGES AND PRELIMINARY RESULTS

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Terrestrial, airborne and spaceborne photogrammetry surveys can be employed in glaciological research to obtain glacier topography, volume change and mass balance data. This MSc research project seeks to employ high quality processing of aerial photographs taken in 1986 and 2006/08 in order to compute volume changes and mass balance on two New Zealand glaciers. The aerial photographs have been kindly supplied by New Zealand Aerial Mapping Limited (NZAM) in a digital format, allowing their digital manipulation by means of a digital photogrammetric workstation. Rather than rely on published topographic sources such as NZTopo database, this project will reassess the aerial photographs acquired in 1986 using consistent photogrammetric processing. This processing is highlighted concerning the special characteristics of a glacier surface, such as the lack of contrast on featureless snow, and the difficulties of finding suitable Ground Control Points in glacier surroundings. This presentation will outline the methodological approach adopted, the research challenges and some preliminary examples on Brewster glacier.

New approaches to interpreting archived oblique aerial glacier photography

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An outstanding record of glacier change is held in the end of summer snowline aerial photography archive. Calculation of glacier parameters from these oblique images has traditionally been done using “expert” subjective methods. This limits the analysis possible to relative measures and makes comparison to glacier changes using other methods problematic. The recent evolution of software that simplifies the generation of maps by orthorectifying oblique photos may provide a method of objectifying measurements from this photographic archive. Such software is reliant on either clearly identifiable ground control points, or knowledge of camera position and orientation at the time the photos were taken. Unfortunately this information is rarely available. Google Earth now provides the ability to manually align oblique photos with the Google Earth satellite imagery and report the position of the “camera” that relates to the photo’s alignment. The use of the “eyeometer” for alignment avoids the need to select ground control points as the analyst effectively uses all features within the image to provide alignment guidance. The camera position and orientation reported by Google Earth may then be used as input to the orthorectification software.
In an effort to test this process, it has been trialled on images from the snowline photo archive of the Rolleston Glacier leading to generation of glacier area, ablation area, accumulation area, terminus elevation, end of summer snowline elevation values. These values have then been compared to GPS survey results of the same parameters indicating the method holds promise.

A CENTURY OF ICE RETREAT ON KILIMANJARO: THE MAPPING RELOADED

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The glaciers of Kilimanjaro/Kibo have attracted interest for over a century. Since their first description following the ascent by Meyer (1889), their dramatic retreat has been characterized by numerous studies [1-6]. While in situ observation and ground mapping have been originally used to map ice bodies over Kibo [7-8], remote sensing techniques via aerial photography/photogrammetry and satellite imagery have become the method of choice to update the glacier boundaries assessed by Meyer.

However, beyond the apparent ease of this problem lies the difficulty to interpret ice bodies over rugged topography in images often affected by snow. The required consistency associated with mapping the obvious retreat of glaciers in new images further complicates the exercise as new ice boundaries are expected to fit within previously published maps. This issue, inherent to the creation and analysis of time series of ice retreat, can thus be affected by the propagation of errors associated with disputable interpretations of ice bodies and/or inaccurate positioning of source imagery.

In updating the areal extent of ice on Kibo using a recent image from Kompsat (June 2011), we show that substantial errors and inconsistencies have propagated throughout the literature with respect to the identification of glaciers and their boundaries. This justified that the time series of ice retreat be revisited, starting with an alternative interpretation of the 1912 photogrammetric survey of Klute [7], and later ground observations of Humphries [8]. A series of nine satellite images from 1975 to 2011 was then orthorectified in a consistent fashion to support the reliable mapping of ice. The use of three-dimensional visualization techniques enhanced and facilitated the interpretation of ice boundaries. In addition to providing a consistent dataset about ice retreat, this study corrects significant errors and clarifies existing disputes about the location of some of the ice bodies. Finally, the 100-year retreat was investigated using a segmentation of the area based on topographical measures. We show that the rate of retreat over the plateau and southern icefield are significantly less than that of the north-facing steep side. This suggests that ice on the Kilimanjaro may remain longer than originally projected by Thompson et al. [4].

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SIRG Fieldtrip Feb 14th 2012

Mueller Glacier - Point Niccolo – Tasman Lake

This year the SIRG field trip will take place in Aoraki/Mount Cook National Park and will consist of 3 activity options. Plus a Glacier Explorers trip on Tasman Lake. We will round off our days excursions with dinner at the Glentanner restaurant before returning to Twizel.

Option 1
Point Niccolo Exploration
with Ray (DOC)

Interpretative walk up to a little visited view point. This trip will involve 4 hours of walking including untracked sections and some scrub.

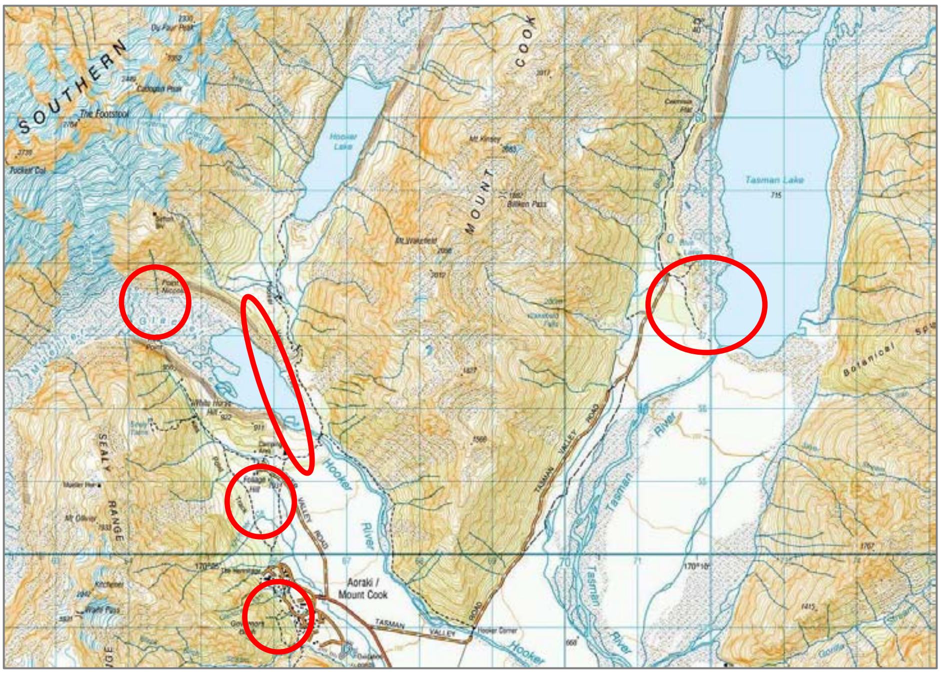
Option 2
Moraine Meander
with Alice

Explore the Mueller & Hooker moraines with Alice who has first-hand experience with latest dating techniques.

Option 3
Village Chill-out

Plan your own afternoon including complimentary 3-D movie at Hermitage Hotel. Check out DOC Visitor Centre, Hillary Centre, cafes or choose walks from 30 minutes up to 2 hours.

11:00	Morning talk session ends. Get packed lunch and bag ready to depart for Mt Cook village. We need to depart by 11:15am.
12:15	Arrive at Mt Cook village. Options 1 and 2 go to White Horse Campground. Option 3 heads into village.
12:30	Walk options set out on afternoon trips.
16:30	All groups rendezvous at White Horse campground and drive out to Tasman Valley Blue Lakes car park.
17:00	Meet Glacier Explorer guides and walk an easy 30 minutes to Tasman Glacier Lake. Boat trip on Tasman Lake. This is an impressive trip where you will get to see massive icebergs up close.
17:30	Depart from Tasman Valley and head to Glentanner for the workshop dinner
21:30	Depart Glentanner and return to Twizel Rowing Complex.



Map of Aoraki/Mount Cook National Park, highlighting locations of field trip activities.

Options 1 and 2 are likely to take place even if it is a bit wet, although will be cancelled (or shortened) if heavy rain occurs. The boat trip will not run if winds are strong or if rain is heavy. Please note that it can be very cold out on the boat even if it is a warm sunny day. If the boat trip is cancelled, then we will spend more time in the village and view the 3-D movie. People will need to advise of their preferred option by the afternoon tea break on Monday. Please note that we will need to keep group sizes for option 1 and 2 relatively even (so as to prevent a very large group), so people need to remain flexible.

Gear List

Waterproof jacket
Overtrousers (optional but great if wet)
Warm layer (i.e. thermal top or fleece jacket)
Day bag
Lunch (provided)
Drink bottle
Sunhat/ Sunscreen / Sunglasses
Warm hat & gloves
Boots or sturdy gym shoes for walking
Camera

People wishing to walk to Point Niccolo should have boots, and be prepared for some subalpine scrub which is very scratchy. Lightweight, windproof trousers are ideal, or you can do the good old-fashioned kiwi thing and wear long-johns under your shorts, which will ward off the vegetation and keep you warm on the boat.

If you have any questions about the field trip options please feel free to contact me.
Regards,
Heather Purdie (heather.purdie@canterbury.ac.nz)