Snow and Ice Research Group (SIRG) New Zealand

Annual Workshop
Mt Ruapehu

12th to 14th February 2007

***Ruapehu Crater Lake from Tahurangi (2797m)**. Photo by Andrew Mackintosh*

PRESENTATION TIMETABLE

Time	Presenter	Topic
Monday		
2:00	Heather and Andrew	Welcome & Introduction
2:15	Trevor Chinn	Glacier Mass Balance Measurements in N.Z. History and Development
2:30	Jordy Hendrix (for Jim Salinger)	Glacier volume changes in the Southern Alps - Trends and variations from snowline monitoring
2:45	Andrew Mackintosh	On the response of maritime glaciers to climatic change
3:00	Afternoon tea	
3:30	Dorothea Stumm	Index-stake Mass-balance measurements on Rolleston Glacier
3:45	Pascal Sirguey	Operational and Improved Snow Mapping at Subpixel resolution in the Waitaki Basin using MODIS/TERRA
4:00	Tim Kerr	Comparison of CROSS-Mountain precipitation profiles from around the world
4:15	Brian Anderson	Response of KA ROIMATA O HINE HUKATERE Franz Josef Glacier to Climate Change
4:30	Uwe Morgenstern	Ice dating on Tasman, Franz-Josef and Fox Glaciers
4:45	Simon Allen	Geomorphic Hazard Modelling in the Mount Cook Region: Initial Results from ASTER based Glacial Lake MAPPING
5:00	Wolfgang Rack	Tidal flexure and ice flux in the grounding zone of Jutulstraumen, Antarctica
7.00 pm		Dinner at Lodge
8.00 pm	Harry Keys	After dinner talk about Mt Ruapehu
Tuesday		or Wednesday depending on weather
8:30	Shelly McDonnell	Drainage system development of the Wright Lower Glacier, Antarctica, over a season
8:45	Martin Brook	Late Quaternary glacial history of Mt Allen, southern Stewart Island
9:00	John Orwin	Identifying Phases of Moraine Deposition Using Lichen Size-Frequency Distributions and the U2 Statistic
9:15	Tom Paulin	Short-term velocity variations on the Tasman Glacier
9:30	Jordy Hendrix	An Update on NIWA'S Snow and Ice Monitoring Network
9:45	Erik Bollmann	The influence of atmospheric circulation on interannual variability of snow accumulation at the Broken River Ski Field, Craigieburn Range, New Zealand
10.00	Trevor Chinn	Two ELA's Make Tropical Glacier recession a Double Whammy?
10:15	Wendy Lawson	Southern Hemisphere Cryosphere: a new project with Chile
10:30	Morning tea	
Discussion		
11:00	Wendy Lawson	GEF meeting report, glacier monitoring programme
11:15	Tim Kerr	Is there such a thing as a representative glacier?
11:30	Blair Fitzharris	GLIMS regional chief position (Sean Fitzsimons)
11:45	Blair Fitzharris	Authorship & writing of chapter for GLIMS book
12:00	Brian Anderson	Future structure of SIRG (International Glaciological Society)
12.15		Other items to discuss

GEOMORPHIC HAZARD MODELLING IN THE MOUNT COOK REGION: INITIAL RESULTS FROM ASTER BASED GLACIAL LAKE MAPPING

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On a global scale, related damages from natural hazards occurring in glacial environments are in the order of €100 million (Kääb et al. 2005). The most devastating and far reaching hazards have involved complex process interactions, including ice and rock avalanches, glacial lake outbursts, and debris flows. Recent and continued climate change has had a profound effect on geomorphic processes operating in the glacial environment, thereby shifting zones of hazard initiation and subsequent adversely affected zones of human use. Because of the inaccessible terrain often characterising glacial environments, the large spatial scale that may be a feature of complex process interactions, and rapidly changing conditions due to global warming, the application of integrative earth-observation techniques in any regional assessment of glacier related hazards is considered very beneficial (Huggel et al. 2004). The heavily glaciated Mount Cook region provides a highly dynamic environment within which new methodologies can be developed and tested to produce an integrated assessment of glacier related hazards. Ultimately scenario simulations of glacial ice and possible permafrost distribution will be used to model future hazard interaction in response to changing glacial conditions.

In a preliminary step towards modelling glacial hazard processes, initial work has focused on ASTER based mapping of geomorphic terrain features, beginning with glacial lakes. Water turbidity exerts the greatest control on the reflectance of glacial lakes in the visible and near infrared wavelengths (Wessels et al. 2002). An integrated detection method combining two simple band indices was developed, in order to detect the greatest range of relatively clear to extremely turbid lakes. Significant misclassifications were observed involving areas of blue glacial ice, crevasse fields, and edge effects along glacial margins. A colour space transformation was incorporated into the model, and proved highly successful in removing misclassified pixels and allowing accurate lake mapping. Subsequent model testing in the glacial lake dominated Mount Everest region of the Himalayas and Wallis region of the Swiss Alps also gave good results. Because it does not require the use of a DEM for shadow removal, the model provides fast, effective first order mapping of glacial lakes in remote regions, with repeat imagery allowing automated monitoring of lake growth for hazard management purposes.

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RESPONSE OF KA ROIMATA O HINE HUKATERE *FRANZ JOSEF GLACIER* TO CLIMATE CHANGE

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The recession of small glaciers and ice-caps are will contribute more to sea-level rise in the coming century than the ice sheets of Greenland and Antarctica. The glaciers of New Zealand also provide information on climatic variations in a part of the world with few terrestrial records of past climate. The Franz Josef Glacier has previously been identified as a glacier which is sensitive to climate change, and which also has the best record of terminus position in the Southern Hemisphere. Here we develop a coupled mass-balance and glacier flow model and use it to (a) assess the climatic influences on the mass balance and length of the glacier from 1894 to 2005, (b) use a simulation of 20th century advance and retreat to evaluate the performance of the model system, and (c) use the model to predict the future behaviour of the glacier, based on future climate change scenarios.

The reconstruction of mass balance from 1894 to 2005 leads us to the conclusions that there has been a reduction in mass balance over the period at a mean annual rate of 0.02 ma^{-1}, and the climatic driver behind this reduction in mass balance is predominantly temperature increase. A simulation of glacier length, using the mass balance reconstruction, tends to overestimate glacier length in the early part of the simulation period. Adjusting the corrections in the early part of the Hokitika climate record allows glacier length to be closely simulated.

Simulations of future glacier length under different climate scenarios all result in the steep ‘tongue’ of the glacier being lost to recession. Under the ‘mean change’ scenario the glacier would reduce to 6.5 km long from its present 11.3 km by 2100, with a reduction in volume of 38%. This recession would be greater than that seen during the 20th century.

THE INFLUENCE OF ATMOSPHERIC CIRCULATION ON INTERANNUAL VARIABILITY OF SNOW ACCUMULATION AT THE BROKEN RIVER SKI FIELD, CRAIGIEBURN RANGE, NEW ZEALAND

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For different locations around the world, e.g. western parts of the US, Europe, Asia or for the Fiordland region of New Zealand, it has been shown that interannual variations in snow accumulation are influenced by various atmospheric circulations. The goal of this study is to understand the variability of interannual snow accumulation at the Broken River Ski Field, Craigieburn Range and identify if there are correlations with atmospheric circulation indices. An overview of the data and preliminary finding will be presented.

Two main types of data were used in this study; snow data and climate data. The snow data were derived from three different sources. From a snow course site at 1,750m in Alan's Basin, data on snow water equivalent were available for the years 1962 – 1973 and were digitised from Moore and Prowse (1988). Snow depth was calculated using a snow density graph for the Craigieburn Range. For the Ski Basin site at 1,550m manual observations of snow depth were made by the Forest Research Institute for the period 1971-1982. In 1991 the Department of Geography at the University of Canterbury started the collection of data from the climate station and hourly data are available up to the present. These data had to be filtered and corrected because of different problems in each data recording method. The climate data used were a collection of atmospheric circulation indices. These included the Trenberth circulation indices as well as the Kidson (2000) synoptic typing and the SOI.

Initial statistical analysis shows significant correlations between some of these atmospheric circulation indices and a measure of snow depth. The results suggest that snow depth variations at the two locations are controlled by different atmospheric circulation indices.

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LATE QUATERNARY GLACIAL HISTORY OF MT ALLEN, SOUTHERN STEWART ISLAND

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Until relatively recently, the extent of late Quaternary glaciation on Stewart Island, off the south coast of the South Island, was thought to be limited to the Mt Anglem area in the north of the island[1-3], at c. 980 m altitude. Research that emerged during the late 1990s suggested that glaciers may also have been active on Mt Allen 30 km to the south at a lower elevation (c. 750 m). During regional mapping of basement rocks, Allibone & Wilson[4] noted two arcuate ridges of bouldery rubble on the eastern slopes of Mt Allen. The southern of the two ridges had previously been noted as a landslide deposit[1], while the northern ridge had not previously been described at all. A small debris ridge-dammed tarn has been formed between the debris ridges and the south-eastern slope of Mt Allen at c. 550 m. Allibone & Wilson[4] described the features very briefly in a series of three photographs, without attempting any other form of analysis of the landforms. Hence, the origin and time of formation of these landforms remains equivocal and differences of opinion concern their original process mechanisms, formation and associated climatic implications. Similar small-scale constructive ridges have been identified in the Drakensberg, southern Africa, and have been described as a variety of landforms other than glacial moraines, including block deposits, slope wash and solifluction deposits, protalus ramparts, rock glaciers[5]. The objective of this project is to provide a detailed description of the sedimentology of constructive ridges at Mt Allen so that their origin can confidently be known. Several methods are being used to assess the origin of the landforms, including RA-C_{40} index, macrofabric and particle size analysis. Samples from the ridges are being dated using ^{14}C of organic deposits and optically stimulated luminescence (osl). A glacial origin for these deposits would imply an equilibrium line altitude (ELA) below the summit of Mt Allen (750 m). A palynological study of a core taken adjacent to the tarn is also envisaged, and deconvolving whether any glaciation was precipitation or temperature-led will prove intriguing if it can be determined[6].

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GLACIER MASS BALANCE MEASUREMENTS IN N.Z.HISTORY AND DEVELOPMENT

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This presentation is given for field staff currently working on glacier mass balances

Tasman Glacier

Mass balance measurements were initiated by the Ministry of Works for the NZ. Electricity Department hydro-power water resources. Work commenced in 1965 with the installation of a profile of stakes from the upper ablation zone to the upper neve and ceased at the end of the 1974-75 year. Survey parties flew in by ski plane on 6 to 8 visits per year and took measurements on the walk out. Because of the deep snowpack, the depths were measured in increments. Sites were marked by 3m long, guyed aluminium stakes with an area of sawdust spread at the base. There were many instances of stakes being overtopped or otherwise lost. Many possible methods of locating lost poles were considered but to no avail. Sampling at each stake used a Mt Rose snow sampler to take a core down to the previous sawdust layer to gain the snow depth change. Snow density was easily gained (provided there was little wind) by weighing the sampler and snow on a specially calibrated spring balance. Cores could be taken to 3 – 4m in winter and to 2-3m in the ablation season. The Sipre auger was only used to sample stratigraphy at the upper pole. Winter balance (Bw) snow depths varied from 4m to over 7m and net balances (Bn) from 3m to 4m. The summer surface was marked by sawdust, but if a pole was lost then so was this vital datum. The summer surface was usually recognisable in lower neve, but rarely at the highest stake. In 1971-72 the surveys were extended to include the full length of the ablation zone, using a hot-point hot water drill for the 15m deep ablation poles, and geophysical measurements were also made.

Ruapehu glaciers

Following a lahar railway disaster in 1953, from 1954 the glaciers of Ruapehu were monitored for changes. This work led to a mass balance study by Kells & Thomson on the Whakapapanui Gl.

Ivory Glacier

At a request for an IHD representitive basin an aerial reconnaissance was made in 1967 to assess the suitability of the Brewster, Siege, Victoria and Ivory glacier options. Brewster had a snout on the edge of a cliff and any advance would destroy the water discharge measuring site, the Siege was eliminated because of unsuitable topography and a small icefall. Victoria was long and debris covered with a steep headwall. The Ivory was an easy choice. In April 1968 the first stake layout was installed with the assistance of the mass balance handbook of Stanley and Ostrem. The stake types and procedures were similar to those used on the Tasman Glacier. Helicopters were used to put survey parties into the remote glacier 4 to 6 times a year, using tent camps for the first 2 years. Mass balance values were strongly negative for all of the 6-years of the study period from 1968-69 to 1974-75. In addition, there was considerable mass loss to the expanding proglacial lake. By 1990 the glacier had almost completely disappeared, prompting the question what was thw Ivory representative of?

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TWO ELAS MAKE TROPICAL GLACIER RECESSION A DOUBLE WHAMMY?

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Tropical glaciers have a number of distinctive mass balance characteristics as a result of their low latitudes. There are no summer/winter accumulation cycles, rather, daily temperature range is greater than the annual range and the position of the ELA is governed by time since the last snowfall. Precipitation is controlled by migration of the Intertropical Convergence Zone (ITCZ) which brings wet and dry seasons. ELAs for tropical glaciers should be measured at end of the dry season.

Near the equator, the free air 0ºC isotherm almost reaches 5000m, so that equatorial glaciers occur on mountains, which rise above "the weather" with summits above the height of free convection. Here precipitation declines markedly, while the lower glacier is fed by orographic precipitation. On some tropical glaciers this decline can lower precipitation to below ablation (sublimation) amounts creating an "upper ablation zone". In a steady-state climate this zone will be ice-free, but in a warming climate, there will be a second ELA lying between residual ice and the glacier upper névé. The summit glaciers of Kilimanjaro lie in such a zone, and currently exhibit spectacular morphology of irreversible recession. The concept of a second ELA introduces challenges when deriving values for ELA and balance gradients for these glaciers. Measurements made on the glaciers of eastern Africa show that there has been an almost catastrophic recession since the 'Little Ice Age'. The low to negative accumulation gradients of tropical glaciers mean that a negative shift of the mass balance gradient curve may, in addition to increasing net ablation, move the upper névé into an ablation zone.

Table 1. Area loss in km^2 of east African and selected S. American tropical glaciers.

REGION	FROM	TO	AREA 1	AREA 2	LOSS %	Present ELA
Kilimanjaro	1912	2003	12.1	2.51	79.2	5730m to 5360m.
Kenya	1899	1993	1.56	0.41	73.7	
Rwenzori	c.1850	1990	10	1.67	83.0	c. 4800m
Irian Jaya	c.1850	1990	19.3	1.67	91.3	
Huascaran	1920	1970	71	58.2	18.0	
Cord. Blanca	1920	1950	93.7	84.2	10.1	
Bolivia	1920	1975	28.6	25.0	12.6	

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AN UPDATE ON NIWA'S SNOW AND ICE MONITORING NETWORK

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Depending on the pace of global climate change over the next 20-100 years snow and ice in New Zealand are two resources that are likely to be subject to significant change. Such changes will have an impact on the alpine landscape and the use of the associated resources (e.g. water resources, hydroelectricity, agriculture and tourism/skiing). To better understand these changes in snow and ice, a national monitoring network has been proposed. Unlike other countries around the world, New Zealand does not currently have a seasonal snow monitoring network.

At the GLIMS/SIRG meeting in Twizel in 2006, NIWA made a commitment to establish a snow and ice monitoring network for New Zealand. This presentation will provide an update on progress towards this goal. An overview of the locations and equipment will be presented, outlining the technical challenges and restrictions on the design and implementation of a high elevation monitoring network. Future expansion plans will also be discussed.

COMPARISON OF CROSS-MOUNTAIN PRECIPITATION PROFILES FROM AROUND THE WORLD

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It is not well known how the precipitation regime of the Southern Alps,

New Zealand compares to that which is observed in other mountainous regions of the world. A common form of representing precipitation distribution in the Southern Alps is through cross-mountain average annual precipitation transects (Chinn 1979; Griffiths and McSaveney 1983; Sinclair et al. 1997; Henderson and Thompson 1999). These transects show a similar form with a peak in average annual precipitation associated with the first barrier the mountains present to the predominant wind, then declining totals further to the lee. A new precipitation transect prepared for the Aoraki/Mt Cook region demonstrates this form (see Figure 1).

The U.S. National Climatic Data Center (NCDC) Global Historical Climatology Network Version 2 (GHCN V2) archives precipitation data from around the world. This has been combined with elevation data from the Shuttle Radar Topography Mission (SRTM) and GTOPO30 to prepare average annual precipitation transects for mountainous regions around the world. In this way the Southern Alps precipitation transects are compared to those observed from other mountainous regions of the world.

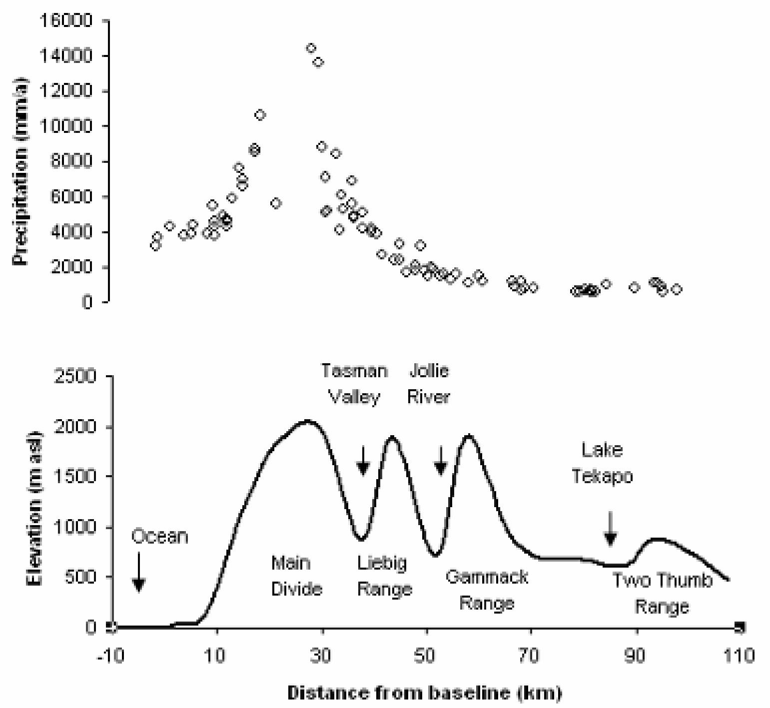

Figure 2. Average annual precipitation totals across a transect through the Southern Alps in the Aoraki/Mt Cook region.

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SOUTHERN HEMISPHERE CRYOSPHERE: A NEW PROJECT WITH CHILE.

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This paper outlines the nature of a collaborative project that is currently being considered for funding in a second round by the United Nations Environment Programme GEF (Global Environment Facility). The overall goal of the project is to assess elements of cryospheric change in Chile, New Zealand, and Antarctica, in order to advance our understanding of patterns and hemispheric environmental change in the Southern Hemisphere. The focus is large scale, and on mass balance-related scientific issues with human impact dimensions. Hub partners in the project are CECS in Valapraiso, Chile, and Canterbury University, in Christchurch.

This talk also sets the scene for the discussion to follow, and invites the SIRG community to be involved in identifying New Zealand glaciers that can be considered for inclusion in the final scientific schedule.

DRAINAGE SYSTEM DEVELOPMENT OF THE WRIGHT LOWER GLACIER, ANTARCTICA, OVER A SEASON

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Understanding the hydrological behaviour of glaciers is important for many applications, including predicting climate change, ecosystem functioning and satisfying hydroelectricity demands. Most studies of glacier hydrology have focused on subglacial processes, as this is where the majority of water is routed on temperate glaciers. However, in cold-based glaciers, and on temperate glaciers in the winter, most water is drained through the supraglacial network. This study focuses on supraglacial drainage patterns in a cold environment, with a view to apply this knowledge to temperate glaciers. This paper focuses on the seasonal development of the supraglacial drainage system on the Wright Lower Glacier, Antarctica. Seasonal melt progression was monitored during the 2005/06 summer, which entailed gathering meteorological information, ice temperature profiles and sites of observed melt. Meteorological data was collected on the glacier surface using an Automatic Weather Station (AWS), which recorded net radiation, incoming and outgoing solar radiation, air temperature, relative humidity, and ablation. These measurements were in turn supplemented by an AWS located off the glacier surface, which measured solar radiation, relative humidity, air temperature, and wind speed and direction. In addition, four thermistor lengths were installed in the glacier surface, and measured temperatures at 10cm intervals, to a depth of 80cm. These thermistor profiles were installed in a supraglacial channel: in the north-facing wall, the south-facing wall, the channel floor, and in a cryoconite hole. The collated results have been used to develop a qualitative model for supraglacial drainage. These results suggest that meltwater creation and routing is influenced by albedo and aspect. In the winter months, no shortwave radiation reaches the glacier surface, meaning that there is not enough energy to induce melt. However, westerly winds dominate, meaning that more sediment can be transported onto the glacier surface than can leave. This sediment is trapped in topographic depressions and ice deformities, and exacerbates melt, especially in the early melt season (late October-early November). As radiation input increases, melt is observed in sediment covered regions, and on north-facing walls. Towards late November, meltwater begins to flow over the glacier surface, and in this part of the season is largely routed supraglacially. As the season progresses, more water is routed through near surface channels, with cavities forming below north-facing cliffs, and in regions occupied by cryoconite holes. Towards late December, these cavities may open, and enhance drainage from the supraglacial region into the glacier outlet.

ON THE RESPONSE OF MARITIME GLACIERS TO CLIMATIC CHANGE

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Temperate mountain glacier fluctuations are often used to reconstruct climate changes, especially over the last 20,000 years as moraine morphology is preserved. However, glaciers respond to changes in several meteorological variables including temperature, precipitation, insolation, cloud cover, wind speed and humidity and it is difficult to relate glacier fluctuations to just one of these variables. It is often assumed that temperature changes were responsible for glacier fluctuations because of the well-documented and spatially coherent record of temperature changes in ice cores and the apparent synchronicity of glacier fluctuations in widely dispersed areas. Alternatively, 'anomalous' glacier fluctuations which are out of step with local proxy evidence are explained by variations in precipitation. Numerical modelling allows testing of competing hypotheses and isolation of the dominant 'drivers' of mountain glacier fluctuations. We present two cases from New Zealand: a distributed energy balance modelling study of the Brewster Glacier, a 3 km long cirque glacier in a high precipitation area; and a coupled degree-day, glacier-flow model of the well-known Franz Josef Glacier. At Brewster Glacier, the influence of all direct and indirect meteorological variables affecting surface mass balance is assessed, and it is shown that temperature is the dominant variable affecting the glacier. Precipitation variability is less important and we illustrate that a 38% increase in local precipitation is required to balance a 1°C warming at this site. At Franz Josef Glacier, we use a simpler model to simulate the glacier length variations during the last ~13,000 years; advance to the Waiho Loop cannot be explained by precipitation variability unless unrealistic increases (+400%) are invoked but temperature changes of -1 to -4°C can explain all length fluctuations in a satisfactory manner. Our results, which are independent of the model type, glacier size or time frame considered, indicate that high-precipitation glaciers in New Zealand are sensitive to small temperature changes and are rather insensitive to variations in total precipitation. We speculate that global retreat of temperate maritime glaciers since the last termination may reflect a similar sensitivity to temperature changes, in an analogous fashion to 20th Century glacier retreat, which resulted from a ~0.6 °C global warming.

ICE DATING ON TASMAN, FRANZ-JOSEF AND FOX GLACIERS

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Tritium dating was applied to three glaciers of Mount Cook National Park to reveal the length of potential environmental records in the ice. No ice cores were available yet but we collected ice samples along the glacier surface. This allows for identification of the specific tritium peaks that occurred in snow and rain over the last 50 years. The atmospheric tritium history was found to be preserved in the ice despite meltwater processes.

The terminus ice of the steep and fast flowing West Coast glaciers Franz Josef and Fox Glacier is only 40 and 50 years old, respectively. However, the Tasman Glacier on the west side of the Southern Alps contains older ice. Samples collected along the glacier surface covering the extent between the snowline and the start of moraine cover reveal the age profile for the upper ice layers spans 90 years to the end of the white ice. The older ice downhill is not accessible on the surface (from this point it is covered by rock debris), but ice thickness at the end of the white ice is still several hundred meters, suggesting an ice record of several hundred years.

IDENTIFYING PHASES OF MORAINE DEPOSITION USING LICHEN SIZE-FREQUENCY DISTRIBUTIONS AND THE U² STATISTIC

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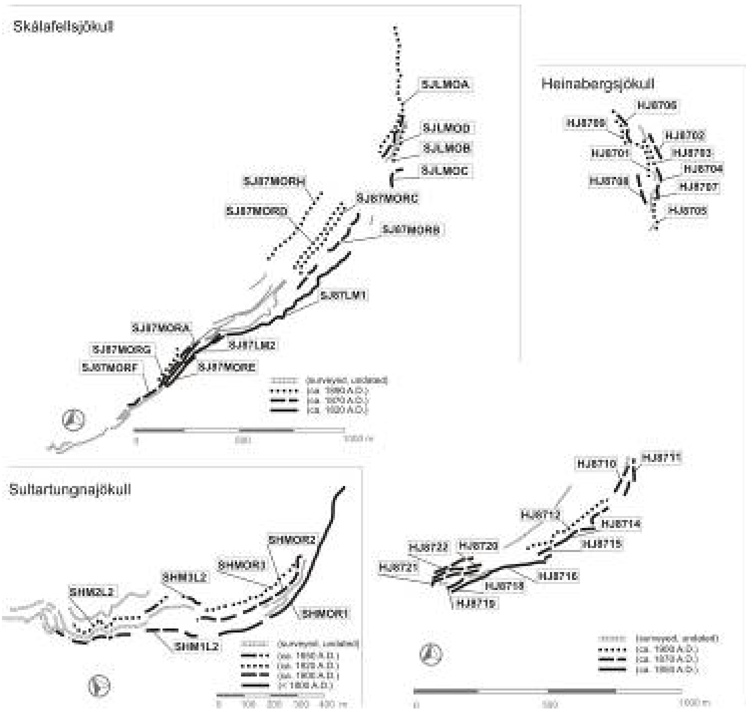
Statistical analysis of lichen size-frequency distributions from complex suites of dated and un-dated Little Ice Age (LIA) moraine fragments was used to infer moraine depositional phases for Skálafellsjökull and Heinabergsjökull, two adjacent Vatnajökull outlet glaciers in southeast Iceland. The statistical analysis was based on a novel use of the goodness-of-fit statistic, Watson's U^2, which provides a measure of 'closeness' between two frequency distributions, combined with cluster analysis. The technique was successful in identifying and clustering 'like-historied' moraine fragments on the basis of lichen size-frequency distributions from dated and uncertain age moraine surfaces. Interpretation of the spatial distribution of the U^2 cluster results and their implications for distinct moraine depositional phases were corroborated by previously published tephra dates. The spatial distribution of the moraines in each U^2 cluster suggest that Skálafellsjökull experienced three phases of moraine deposition, including a phase of significant ice margin fluctuations after the LIA maximum depositional phase. In contrast, the three moraine depositional phases identified for Heinabergsjökull indicate that this ice margin was more digitate with two phases of moraine deposition that breached older moraines. The mapped U^2 moraine clusters clarified the behavior of the ice margins at Skálafellsjökull and Heinabergsjökull and revealed more complex and detailed spatial relationships than possible from lichen and tephra derived dates alone. The success of the U^2 statistical analysis suggests that the technique may be useful in augmenting traditional lichen surface dating as well as differentiating between other depositional landforms that support lichen populations, such as rock avalanche deposits.

Figure 1
Moraine depositional phases identified using the U^2 cluster results. The solid and dashed black lines indicate U^2 clustered moraine crests and the grey hatched lines indicate surveyed moraines crests without lichen analysis. The dates in brackets are based on McKinzey et al. 2004, 2005.



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TIDAL FLEXURE AND ICE FLUX IN THE GROUNDING ZONE OF JUTULSTRAUMEN, ANTARCTICA

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Large amounts of the grounded Antarctic ice are drained through narrow outlet glaciers to floating ice shelves. Grounding zones, the transition regions from grounded to floating ice, are dynamically active regions, which react sensitively to changes in water level and mass balance. Jutulstraumen is a prominent outlet glacier in Dronning Maud Land, Antarctica, which drains an area of about 125.000 km^2 to the Fimbul Ice Shelf through a narrow valley at about 1°W, 72°S. We present a new assessment of the ice dynamics near the grounding line of Jutulstraumen, based on 3 day ERS SAR repeat pass data, radio echo sounding data, and a tide model.

The grounding zone is characterised by almost uniform ice thickness and small bedrock slope between km 10 and 20 (Fig. 1b). A steep rise of radar reflectivity from the ice bottom suggests the position of the grounding line at km 20. Rising reflectivity at km 10 may be a consequence of changing bedrock properties due to temporary floating. The local minimum of reflectivity between km 15 and 20 may be caused by bottom crevasses due to large horizontal velocity. A multitude of combinations of interferometric SAR pairs is used to derive the ice bending in the tidal flexure zone. The deformation pattern confirms the complex bedrock topography. Possible grounding line positions are derived from differential interferograms (DINSAR) by using a threshold for differential vertical displacement. Depending on DINSAR combination, grounding line positions move back and forth by as much as 7 km (Fig. 1 c). Vertical displacement and ice thickness is input to a simple 2D elastic plate model in order to describe ice flexure in dependence of water level [Smith, 1991]. This is used to derive Young's elastic modulus of ice (E). Taking $E = 9\ GPa$ and fitting the point of maximum bending to the observation yields a grounding line position at km 20.

Finally, the ice flux directly upstream the grounding line as well as ice flux and bottom melting downstream the grounding line are derived (Fig. 1a). The outflow of Jutulstraumen close to the grounding line (full sliding) amounts to 15.74 Gt/a, which is close to the total accumulation in the catchment basin (14.1 Gt/a), and amounts to 8.16 Gt/a on the freely floating ice shelf. Average basal melting at the first 33 km of floating ice amounts in average to approximately 10 m/a.

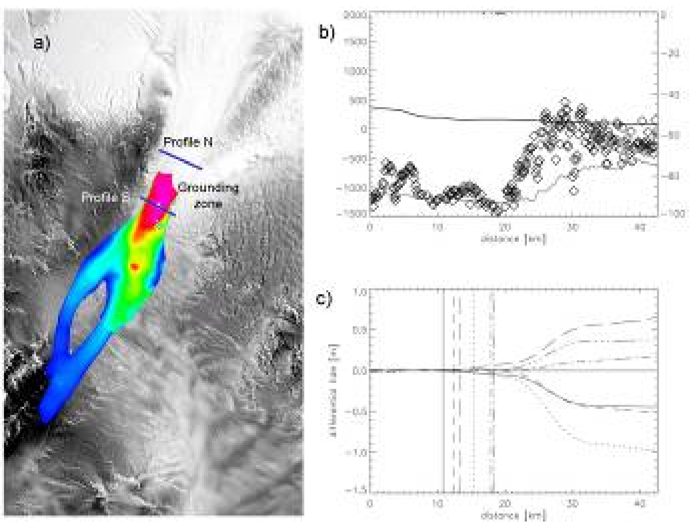

Fig. 1:

a) Surface velocity derived by ERS SAR interferometry on grounded ice and

b) Reflection amplitude, surface and subglacial topography

c) Tidal deflection from DINSAR

Reference:

Smith, A., 1991, The Use of Tiltmeters to Study the Dynamics of Antarctic Ice Shelf Grounding Lines, J. Glaciol., 37 (125), 51-58.

GLACIER VOLUME CHANGES IN THE SOUTHERN ALPS – TRENDS AND VARIATIONS FROM SNOWLINE MONITORING.

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Ice volume changes for the period 1977- 2005 are calculated for each index glacier and extended to the whole of the Southern Alps using the New Zealand glacier inventory. There has been only small loss due to mass balance, but significant loss of ice volume for larger glaciers due to calving into growing glacial lakes and trunk down wasting. Ice volume for the Southern Alps has been estimated to decrease by 17% over this period. The majority of this loss is from 13 of the largest glaciers in response to a regional warming of 1°C since the late 19th century. The mass balance changes demonstrate considerable interannual variability driven by climate factors.

(Presented by Jordy Hendrikx on behalf of Jim Salinger)

OPERATIONAL AND IMPROVED SNOW MAPPING AT SUBPIXEL RESOLUTION IN THE WAITAKI BASIN USING MODIS/TERRA

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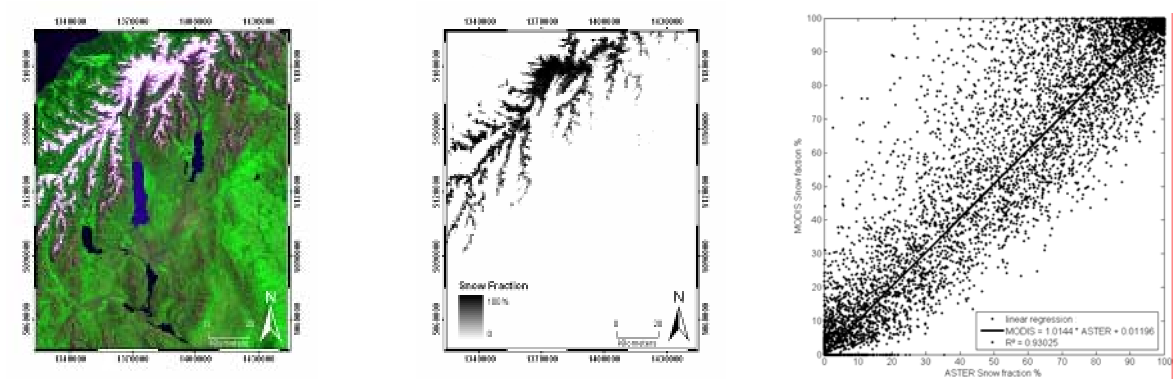
With its daily repeat time and multispectral capabilities, MODIS/TERRA is able to provide an operational monitoring of snow cover parameters and snow pack dynamics in remote area. To process extensive time series, we created a fully automated processing method (MODImLAB) that implement a state of the art atmospheric and topographic correction in mountainous terrain (Richter, 1998), a constrained linear unmixing technique providing subpixel snow fraction extraction capability (Nolin et al., 1993) and an innovative multispectral fusion method (Ranchin and Wald, 2000) allowing us to improve the resolution of the snow map from 500m to 250m. To evaluate the performance of the method, we took advantage of the simultaneity between ASTER (15m) and MODIS sensors, both on the TERRA platform. Four pairs of simultaneous acquisitions MODIS/ASTER covering various conditions of snow cover were used to validate our final product. An average coefficient of determination R^2 of 0.85 for the four granules shows a very satisfying performance of the method. Thanks to the fusion algorithm, we also achieved a significant improvement in our ability to classify snow in mountainous terrain by producing 250m (instead of 500m) snow maps that will help us provide better estimates of the snow water resources.



(a) (b) (c)

Figure 1 - Estimation of the Snow fraction for granule 2002365.2235 (Upper Waitaki Area, South Island of New Zealand, 31 December 2002 22:35 GMT): (a) False color RGB composite from bands 1,2 (250m) and 3 (fused to 250m). (b) Result of unmixing using bands dataset at 250m. (c) Snow fraction from MODIS 250m fused bands versus reference.

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INDEX-STAKE MASS-BALANCE MEASUREMENTS ON ROLLESTON GLACIER

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In New Zealand, there are long-term programs to monitor glacier mass balances. On Franz-Josef, Brewster, Glenmary, Fox and Whangaehu Glacier the mass balance is measured with the glaciological method. These measurements started in the year 2000 or later. End-of-summer snowlines (EOSS) are a proxy for the mass balance. An extensive annual EOSS survey has been started in 1977. It provides excellent spatially distributed mass balance proxy data.
Index-stake mass-balance measurements on Rolleston Glacier complement these mass balance programs in the Southern Alps of New Zealand ideally. In autumn 2005, the first stake was installed on Rolleston Glacier. For Rolleston Glacier EOSS records are available since 1977. Since August 2005, there is a nearby climate station at Arthur's Pass that measures temperature, precipitation and solar radiation. This climate data suits very well for mass balance modelling because it is nearby the glacier on a relatively high altitude of 740 m a.s.l. The Craigieburn Forest climate station, 30 km away from Rolleston Glacier, records extensive climate information since 1964, and provides together with the EOSS measurements a good mean to reconstruct past mass balances. Energy balance models that have been successfully applied to other mass balance glaciers can be applied to Rolleston Glacier and verified with its stake mass balance.

Field work on Franz Josef and Brewster Glaciers, South Island (by Andrew Mackintosh and Julian Thomson)