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Ice

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Contents

Cover picture: Ice discs in a pool near Palmer, Alaska, USA. The air temperature was about –23°C. This picture was taken by Brian Miller in January 2013.

From the Editor

Dear IGS member

Again I have to apologise for the lateness of the current issue of *ICE*. Although we are already more than halfway through 2013, this is the first issue of the year. As always, we hope to catch up towards the end of 2013.

The current issue the IGS is facing now, as I mentioned in my last editorial, is how we will migrate towards open access. One thing is clear; we will most probably lose quite a bit of revenue from lost subscriptions. These subscriptions have subsidized a lot of our activities, meaning that we will have to restructure our business model. Our symposia, for example, will have to be completely self-sustaining. What this means is that we will no longer be able offer four free pages in an *Annals* issue, instead adopting the same page charge policy as we do with the *Journal*, i.e. full page charges will be compulsory (though the page charge rate for *Annals* is currently less than that for the *Journal*). Participants in the various symposia will no longer receive a free hard copy of the thematic *Annals* issue related to the theme of the respective symposia, but instead will have the option to purchase a copy with an additional payment on top of the registration fee. They will, however, get full online access to the *Annals* issue in question.

ICE will be online only, though we will still produce a few paper copies for those of our long-standing members who do not have easy access to the internet. We are exploring ways of making this an interesting online publication, rather than just a simple PDF.

We are also considering having the default membership include online access only to IGS publications, with hard copies available for an additional payment. Members will, of course, still have full online access to all IGS publications, past and present.

On a lighter note, we have at present close to 900 paid-up members, still some way behind last year and further still from our goal of 1000 members this year. Our institutional subscriptions are similar to last year, and I wish I could be confident in saying that this will continue.

We have now completed programming to enable IGS members to access our material on the Ingenta website. This can be done by signing into our website through the 'IGS member login' located in the top right hand corner of our homepage. This is a welcome new feature as it eliminates the need to log in separately onto the Ingenta site, meaning that you are no longer required to register with Ingenta in order to access our content. Please give it a try and let us know what you think of this new feature.

For papers by UK authors who receive their funding through NERC, we are offering immediate Gold Open Access. For the time being (until our business plan fully embraces open access) we will do so for a fixed price per article of £2300. Once we have fully developed the new business model, the OA price will be based on the number of pages within the article. This is available to all authors, regardless of their country of origin, should they so wish.

Another idea we are contemplating is the introduction of a submission charge to cover the operating costs of our online paper submission system, EJPress. The fee would be applied to all submitted papers irrespective of whether or not they are accepted, and the cost would be non-refundable. Currently, the accepted papers that eventually get published (and for which compulsory page charges are levied) are subsidizing the EJPress online submission system. By charging a submission fee, the cost of the EJPress system will be spread across all users of the system.

Currently, the first four issues of the *Journal* for 2013 have been published, and all accepted papers are now being assigned to the final issue of the year, so things are moving smoothly. The question that continues to crop up, however, is whether or not we should increase the number of issues we publish annually. As we publish everything online as soon as the paper is ready, this may not be an issue. What it may mean is that papers scheduled for, say, a 2014 issue, will appear online in 2013.

The *Journal* impact factor published in June 2013 was 2.882, the highest it has ever been (last year it was 2.3 and the year before 2.6). The *Journal* is consistently in the top 100 of more than 16 200 titles for number of full text downloads at Ingenta: the total number of downloads for the last 12 months was 18 828.

Magnús Már Magnússon
Secretary General

Recent work

United Kingdom

ANTARCTICA

The climate of the Holocene from the James Ross Island ice core.
Robert Mulvaney (BAS), Nerilie Abram (BAS, now ANU), Jack Triest (BAS, now LGGE), Olivier Alemany (LGGE), Louise Sime (BAS), Carol Arrowsmith (NIGL)
Recovered in the 1997/98 field season, a 364 m deep ice core penetrating to the bed of the ice cap on James Ross Island, Antarctic Peninsula, has ice as old as 50 ka at the base. A clear climate signal from the LGM to present has allowed us to reconstruct the climate of the deglaciation and Holocene period. By 11 000 years ago the temperature had risen to about 1.3°C warmer than today's average, then cooled in two stages, reaching a minimum about 600 years ago. The timing is consistent with other research that showed the local ice shelves disintegrated in the early Holocene, but reformed in the mid-Holocene as the local climate cooled. Approximately 600 years ago the local temperature started to warm again, followed by a more rapid warming in the last 50–100 years that coincides with present-day disintegration of ice shelves and glacier retreat. The ice core shows melting during the summer at the summit of James Ross Island is now more common than at any point in the last 1000 years.
Email: rmu@bas.ac.uk

Deep ice core from Fletcher Promontory, Antarctica
Robert Mulvaney (BAS), Emilie Capron (BAS), Emily Ludlow (BAS), Louise Fleet (BAS), Richard Hindmarsh (BAS), Jack Triest (BAS, now LGGE), Carol Arrowsmith (NIGL), Guðfinna Th. Aðalgeirsdóttir (UI), Jérôme Chappellaz (LGGE)
During a single field season, 2011/12, a joint UK–French team drilled a deep ice core 654 m to the bedrock on the Fletcher Promontory. Radar measurements on this ice rise, situated to the south west of the Ronne Ice Shelf, suggest the current topography was established within the past 5000 years. Modelling, underpinned by the radar data, suggest the potential to recover a climate record reaching into the last interglacial period. In addition to reconstructing the recent glacial and Holocene climate of this region, we hope to determine whether there had been a substantial reduction in the local ice sheet thickness and extent (and by extension, the West Antarctic Ice Sheet) during the previous, warmer than present, interglacial.
Email: rmu@bas.ac.uk

Shallow ice cores from the Antarctic Peninsula
Liz Thomas (BAS), Ailsa Benton (BAS), Julius Rix (BAS)
Three ice cores of around 135 m, each spanning around 250 years, were recovered from a transect of the southern Antarctic Peninsula in 2012/13. These cores extend a series of two similar cores collected from further south towards Ellsworth Land in 2010/11. This transect of cores is designed to study the recent climate of the southern Antarctic Peninsula, and the impact of changing sea ice and winds in the Bellingshausen and Amundsen Seas.
Email: lith@bas.ac.uk

Ice-shelf stability in the southwest Antarctic Peninsula
Tom Holt, Neil Glasser (AU), Duncan Quincey (ULeeds), Helen Fricker, Matt Siegfried (Scripps)
We have conducted a detailed analysis of the structures and dynamics of Bach (BIS), Stange (SIS) and George VI Ice Shelves (GVIIS), to determine their current and future stability. Spatial extent and glaciological surface features were mapped for each ice shelf from 1973–2011 using optical and radar satellite images to assess their structural stability, structural evolution and historical dynamics. InSAR and optical-image feature tracking were used to examine the dynamic configuration of the ice shelves from 1989–2010, with repeat ICESat measurements used to evaluate their vertical changes from 2003–08. The formation of two large fractures near the ice front of BIS is linked to widespread thinning (~2 m a^{-1}) and sustained retreat (~360 km^2); iceberg calving along these fractures will alter the frontal geometry sufficiently to promote enhanced, irreversible retreat. On GVIIS, acceleration is measured at both ice fronts linked to a release of back-stresses through continued recession. The most significant changes are recorded at its southern ice front, with ice flow accelerating up to 360% between 1989 and 2010, coupled with widespread rifting and a mean thinning rate of 2.1 m a^{-1}. On SIS, shear-induced fracturing was observed between two flow units, also linked to widespread thinning (~4.2 ma^{-1}). A semi-quantitative assessment reveals that the southern margin of GVIIS is most susceptible to rapid retreat, whilst GVIIS's northern ice front, BIS and SIS are more vulnerable than those remaining on the east Antarctic Peninsula.
E-mail: toh08@aber.ac.uk

Optical televiewer-based reconstruction of density, annual layering, and melt-layer history from ice boreholes: Roi Baudouin Ice Shelf, Antarctica

Bryn Hubbard (AU), Frank Pattyn, Jean-Louis Tison, Morgane Philippe (ULB)

Fifteen boreholes have been cored into or through the Roi Baudouin ice shelf over three Antarctic field campaigns as part of the BELSPO-funded BELISSIMA and IceCon research programmes. As well as drilling into the ice shelf proper, boreholes have been cored into the base of a rift formed from accreting marine ice and into the Derwael Ice Rise. Ice cores have been retrieved from each of these boreholes, which have also been logged by optical televiewer (OPTV). The OPTV logs reveal three key features: (i) a general decrease in luminosity with depth; (ii) regularly-repeated light-dark couplets; and (iii) irregularly distributed and -sized dark layers. Feature (i) is interpreted as a firnification-related decrease in material reflectivity that scales with density. Comparison of OPTV luminosity logs with density measurements of their equivalent core-firn samples yields a coefficient of determination of 0.97, indicating that OPTV luminosity provides an excellent proxy for firn density. Feature (ii) is interpreted as annual layering, allowing OPTV–derived age–depth scales to be reconstructed for both the ice shelf and the ice rise. These scales reveal that the ice rise has a higher accumulation rate than the ice shelf, consistent with the former's ~400 m greater elevation. Feature (iii) is interpreted as intermittent layers of infiltration ice formed as a result of summer melting. These are formed frequently throughout the ice shelf record, but are both less common and thinner in the ice rise record, again consistent with its increased elevation.

The IceCon project continues to 2015, when the 120 m long Derwael Ice Rise borehole will be re-logged by OPTV and the record differenced from the 2010 logs in order to investigate millimetric patterns of vertical strain.

E-mail: byh@aber.ac.uk

The Role of Ice Sheets in the Earth System

David Vaughan (BAS)

The IceSheets Programme of the British Antarctic Survey seeks to accelerate progress in understanding the internal dynamics of the ice sheets of Antarctica and Greenland, the history of these ice sheets, and their interactions with the rest of the Earth System in the past, present and future. We will extend and apply integrated mathematical models and initialization techniques for ice sheet forecasting, incorporating new data derived from satellite mapping of mass/volume change in Antarctica and Greenland, and GPS observations of crustal uplift. Work in quantitative geophysical characterization of basal conditions by seismic, radar and direct access techniques will be extended to incorporate observational descriptions of the ice base into ice-sheet models for the physical modelling of basal processes and hydrology. Similarly, we will use our knowledge of grounding-line mechanics to understand ice–ocean links. In order to assess the potential for rapid sea level rise to occur in response to future warming it is important to understand the causes and sources of past 'meltwater pulse' events. This requires dated histories of ice retreat, based on precise dating of sediments, rock exposure and ice-flow changes. In conjunction with ice-sheet modelling, this will quantify ice-volume variations and contributions of Antarctica and Greenland to Quaternary sea-level change. It will also identify maximum rates of change, enable spin-up of models and allow us to validate models against large-scale changes in geometry. Through sediment core studies we aim to derive records of ocean change that are increasingly being recognized as a critical driver for models of long-term ice-sheet change. Our ocean work is providing new bathymetries crucial for exploring past retreat, while our radar surveys are needed to map the bed at the high accuracy needed for ice-sheet forecasting.

E-mail: dgv@bas.ac.uk

A new approach to West Antarctic Ice Sheet evolution using blue-ice moraines on nunataks

D. Sugden, A. Hein, S. Morrero (UEdin); J. Woodward, S. Dunning (UNN); R. Mottram (DMI)

Did the West Antarctic Ice Sheet (WAIS) survive the last interglacial? We are using nunataks as dipsticks of ice-sheet elevation change to help answer this question. One hypothesis is that the WAIS disappeared in the last interglacial under environmental conditions similar to those of the present. Another suggests the WAIS persisted for at least one and perhaps several glacial cycles. This uncertainty implies that we have much to learn about the principal controls on ice-sheet stability, a situation that undermines current predictions of the future of the WAIS and its effect on global sea-level change. In this project we are testing the two hypotheses using a novel methodology that focuses on nunataks in blue-ice areas. In certain situations moraines are deposited on nunatak flanks and preserve a history of ice-sheet elevation changes over hundreds of thousands of years. In order to test the two hypotheses, we are carrying out a survey of the geomorphology, glaciology and exposure ages in the Heritage Range, a nunatak zone close to the central dome of the WAIS.

E-mail: John.woodward@northumbria.ac.uk

ICE CORES: GENERAL

Understanding sea salt signals in polar ice cores

Eric Wolff (BAS and CU), James Levine (BAS), Xin Yang (UCam), Markus Frey (BAS), Katy Pol (BAS), Nerilie Abram (ANU)

Sea salt in ice cores has been proposed as an indicator of past sea ice extent in the Antarctic. However, the way in which the sea salt aerosol is formed is not yet certain, and the relative influence of ice extent and transport processes is unresolved. The Cambridge p-TOMCAT model has had an open ocean and sea ice sea salt aerosol source applied to it in order to explore this. Model runs with different meteorologies and ice extents are allowing us to construct a calibration. New high-resolution chemical analysis of shallow Greenland ice cores is allowing exploration of the potential for an ice core signal of sea ice there. Finally, experiments to collect blowing snow and aerosol from a winter cruise in the Weddell Sea, June–August 2013, on the *Polarstern* are allowing us to explore the sources of sea salt aerosol, and the role of sea ice in those sources. This work is contributing to international initiatives including the PAGES Sea Ice Proxy Working Group.

E-mail: ew428@cam.ac.uk

Past interglacials in the polar regions

Eric Wolff (BAS), Emilie Capron (BAS), Katy Pol (BAS), Louise Sime (BAS)

Interglacials in the Quaternary are particularly interesting because they represent a climate that in some cases was warmer than today, and in the polar regions we can explore the impact of additional warmth on aspects such as sea ice and ice sheets/sea level. Under the auspices of the EU Past4Future project and the NERC iGLASS project, we are compiling records of climate in the polar regions in the last four interglacials. This involves careful synchronization of ice core, marine and terrestrial records, and of records from the Northern and Southern Hemispheres. Marine isotope stage 5E and 11 stand out as the warmest interglacials of recent times, in which the effect on sea level has particularly to be investigated. The last interglacial (stage 5E) stands out as particularly warmer in the Greenland isotopic record from ice cores. However, exploration of that with isotope-enabled GCMs suggests that the exact amount of warmth that the isotope signal represents is very dependent on knowledge of the boundary conditions, especially, the sea ice conditions around Greenland.

E-mail: ew428@cam.ac.uk

THE ARCTIC AND GREENLAND

NEEM deep ice core, Greenland

Robert Mulvaney (BAS), Nerilie Abram (BAS, now ANU), Ailsa Benton (BAS), Louise Fleet (BAS), Markus Frey (BAS), Liz Thomas (BAS)

BAS participated in the multi-national deep ice core drilling project in Greenland (NEEM). During each of the 2009–11 field seasons we operated a Fast Ion Chromatograph in the field chemistry laboratory, measuring soluble anions along the full length of the core. Our main interest lies in the sea salt aerosol incorporated in the cores, particularly in the past interglacial period, which may be related to changes in sea ice extent.

E-mail: rmu@bas.ac.uk

Optical televiewer-based logging of the NEEM deep borehole, Greenland

Bryn Hubbard, Terry Malone (AU), D. Merton-Lyn, P. Worthington (Robertson Geologging, Ltd), NEEM Consortium Members

Robertson Geologging Ltd's optical televiewer (OPTV) has been physically adapted and data transfer protocols developed to allow the instrument to operate in ice boreholes up to 3 km deep. Consequently, in 2012, the full ~2550 m length of the NEEM deep ice borehole, Greenland, was logged by OPTV. This deep log complements those already acquired in 2010 of the uppermost 650 m of the deep borehole and of a shallow borehole located nearby, extending these earlier records to the ice–bed interface. The newly-acquired OPTV record reveals the presence of several notable glaciological phenomena, including: (i) large-scale luminosity changes along the borehole that are consistent with changing ice facies, including the brittle ice zone; (ii) regularly spaced light-dark couplets at depth within the borehole, provisionally interpreted as annual layering; (iii) occasional planar layers of increased luminosity, each some millimetres thick, provisionally interpreted as dust or ash layers; and (iv) steeply dipping debris-rich basal ice layers in the lowermost ~10 m of the borehole. This research is funded by the Royal Society and UK's NERC.

E-mail: byh@aber.ac.uk; dmlyn@geologging.com

Sediment plume variability in Jökulsárlon, Iceland, from in-situ spectrometry and MODIS satellite imagery

R. Hodgkins (LU), R.G. Bryant (US), M.A. Brandon (OU)

A fundamental problem in studying the hydrology of tidewater glaciers is that their runoff emerges in an inaccessible, submarine location, and therefore cannot be measured or monitored directly. Yet this runoff is fresh, therefore buoyant

in saline fjord waters, and is typically turbid: hence, it tends to form observable, overflow plumes at the glaciers' termini. Tracking the spatio-temporal variability of such turbid plumes offers a means of monitoring tidewater glacier hydrological outputs. In this study, the Total Suspended Solids (TSS) concentration of surface waters in the 23 km^2, glacially fed, tidal lagoon Jökulsárlon, Iceland, is related to surface reflectance measured in situ. TSS and reflectance are well correlated in a wavelength window that corresponds to band 1 of the Moderate Resolution Imaging Spectroradiometer (MODIS) instrument on board NASA's Terra/Aqua satellites. MODIS 250 m resolution daily reflectance imagery can therefore be calibrated to values of TSS using the relationship determined in situ. Imagery shows turbid runoff inputs to the lagoon from the Breiðamerkurjökull glacier at its northern end, and also terrestrial river inputs on its east and especially west margins, plus high TSS values adjacent to the tidal inlet, where strong turbulence is encountered in shallow water. In the April–May interval studied, cumulative Positive Degree Hours are significantly positively correlated with minimum TSS, while the ice-covered proportion of the lagoon is significantly negatively correlated with minimum TSS, suggesting that MODIS-derived plume statistics can track the pre-melt-season evolution of lagoon waters in response to changing hydrological inputs.
E-mail: R.Hodgkins@lboro.ac.uk

Variable history of Quaternary ice-sheet advance in the Beaufort Sea
C.L. Batchelor, J.A. Dowdeswell (CU)
The seismic stratigraphy and architecture of the Beaufort Sea shelf and slope were investigated using a comprehensive grid of high-resolution two-dimensional seismic-reflection data. Three cross-shelf troughs, representing locations of former ice streams draining a 1 000 km section of the Quaternary North American Ice Sheet were examined: the Mackenzie, Amundsen Gulf and M'Clure Strait systems. Dynamics of these palaeo-ice streams influenced ice-sheet configuration and may have forced abrupt climatic change through delivery of ice and freshwater to the Arctic Ocean. A comprehensive understanding of their geometry and dynamics is crucial for constraining numerical models of the former ice sheet. Evidence for two Quaternary ice advances to the shelf break is interpreted from Mackenzie Trough. By contrast, seismic stratigraphy of Amundsen Gulf Trough, 400 km east of the Mackenzie, records at least nine Quaternary ice advances. Here, the outer shelf consisted of several stacked till sheets, extending to the shelf break and forming a trough-mouth fan. The contrasting glacial histories of these neighbouring ice streams were explained by their positions within the past ice sheet: Mackenzie Trough ice stream was situated at the extreme northwest ice-sheet margin, whereas Amundsen Gulf ice stream had a more central location and larger drainage basin, supplying significant quantities of ice and sediment to the Arctic Ocean through much of the Quaternary. This work has been published recently in *Geology*, and was undertaken in collaboration with Dr Jeff Pietras of BP.
E-mail: clb70@cam.ac.uk

Late Quaternary ice flow in a West Greenland fjord and cross-shelf trough system
J.A. Dowdeswell, K.A. Hogan (CU)
Sea-floor landforms and acoustic–stratigraphic records allow interpretation of the past form and flow of Rink Isbræ, West Greenland. Several acoustic facies are mapped from sub-bottom profiler records of the 400 km Uummannaq fjord-shelf-slope system. An acoustically stratified facies covers much of the fjord and trough floor, interpreted as glacimarine sediment from rain-out of fine-grained debris in turbid meltwater. Beneath this facies is a semi-transparent deformation-till unit, which includes buried streamlined landforms. Landform distribution in the Uummannaq system is used to reconstruct past ice extent and flow directions. The presence of streamlined landforms (MSGL, drumlins, crag-and-tails) shows that an ice stream advanced through the fjord system to fill Uummannaq Trough, reaching the shelf edge at the Last Glacial Maximum. Beyond the trough there is a major fan built mainly of glacigenic debris flows. Turbidity-current channels were not observed on Uummannaq Fan, contrasting with well developed channels on Disko Fan, 300 km to the south. GZWs in Ummannaq Trough imply that ice-sheet retreat was episodic, punctuated by several still-stands. There is little sedimentary evidence for still-stands in the inner fjords, except a major moraine ridge marking a Little Ice Age maximum position. On the shallow banks either side of Ummannaq Trough, iceberg ploughing has reworked any morphological evidence of earlier ice-sheet activity. Field work was undertaken on the RRS *James Clark Ross* as part of a major NERC-funded research cruise led by Colm Ó Cofaigh and involving a team of colleagues from several universities.
E-mail: jd16@cam.ac.uk

Hydrology and dynamics of the Greenland Ice Sheet
A. Banwell, I. Willis, N. Arnold (CU), A. Ahlstrom (GEUS, Denmark), M. Tedesco (CCNY), D. MacAyeal (UChi).
We have developed a coupled melt/hydrology model and applied it to the Paakitsoq region of

West Greenland. The model routes meltwater across the surface of the ice sheet and includes the processes of filling and draining of surface lakes and the delivery of the water to the ice sheet bed. It routes the water across the bed in a network of channels that enlarge and contract in response to the flux of water flowing through them. Various components of the model have been calibrated/ evaluated against measured rates of ablation, snowline retreat, lake filling and bulk proglacial stream catchment runoff. A key output of the model is spatial and temporal patterns of water pressure beneath the ice sheet. Our focus over the next 3 years will be to improve the subglacial routing component of the model to allow for a distributed hydrological system (small cavities and/or porous sediments) and the interaction of this with the channelized component. We also propose to couple the melt/hydrological model to an ice flow model in order to calculate patterns of basal sliding and the 3-D velocity/strain field, and the resultant feedbacks on surface topography and therefore melt and surface routing. The model will be tested against measurements of surface velocity/strain made over a variety of time periods (days to years), and used to predict the future response of the ice sheet to predicted 21st century climate change scenarios.
E-mail: afb39@cam.ac.uk

Ice flow and supraglacial lake drainage in West Greenland

P. Christoffersen, M. Bougamont (CU), A. Hubbard (AU), B. Kulessa (USwan)

Collaborative research in Aberystwyth, Swansea and Cambridge is bringing together observational and numerical modelling techniques in order to better understand the climatic forcing of ice flow along the western margin of the Greenland Ice Sheet. Typical for many glaciers in this region is a seasonal cycle of flow linked to surface meltwater production and evolution of the basal drainage system. In this project we specifically studied Russell Glacier in order to better understand the potential mechanisms responsible for seasonal flow changes. Field data were collected in 2009–11 and included geodetic GPS measurements, automatic weather station records and geophysical surveys to determine basal conditions. The location and volume of supraglacial lakes and the spatial pattern of seasonal flow variations were obtained from analysis of satellite imagery, and the flow of the ice sheet was modelled using the higher-order Community Ice Sheet Model (CISM). By bringing together wide-ranging observational data and a three-dimensional ice sheet model with thermodynamics and higher-order flow physics, we developed new insights to the climatic forcing of the Greenland Ice Sheet. Results showed that supraglacial lake drainage events can explain the observed seasonal variation in flow, although the volume of water contained in these lakes is small compared to the overall volume of water forming on the surface as runoff. The research was funded by the UK Natural Environment Research Council (NE/G00692X/1).
E-mail: pc350@cam.ac.uk

Subglacial Access and Fast Ice Research Experiment (SAFIRE)

P. Christoffersen, M. Bougamont (CU), B. Hubbard, A. Hubbard (AU)

The margin of the Greenland Ice Sheet has been thinning persistently over the last several decades, with the highest rates of thinning observed on fast-flowing outlet glaciers terminating in fjords. Although flow of the Greenland Ice Sheet and its numerous outlet glaciers is well known from maps of surface velocity, very little is known about the subglacial environment that enables fast flow. It is commonly assumed that Greenland glaciers slide over hard and impermeable bedrock, but this assumption, although practical, is largely assumed and based on lack of better constraints. The lack of precise information about the bed and related processes is problematic because representation of the glacier bed is one of the biggest sources of error in numerical ice sheet models. About half of the Greenland Ice Sheet is affected by basal motion, which may, at least in some places, occur from deformation of unconsolidated subglacial sediment. In the SAFIRE project, we will use a hot water drill to access the bed of Store Gletscher, a fast-flowing, marine-terminating outlet glacier near Uummannaq in West Greenland. With instruments deployed at the bed and on the glacier's surface and forefield, the project will fully resolve the basal control on ice flow and the glacier's response to iceberg calving, including the effects of meltwater input to the bed. The observational outcome will inform the glacier's sensitivity to atmospheric as well as oceanographic forcing. The project is funded by the UK Natural Environmental Research Council (NE/K005871/1).
E-mail: pc350@cam.ac.uk

Investigating the hydrology and dynamics of Greenland's outlet glaciers

P. Nienow, I. Bartholomew, T. Cowton, A. Tedstone (UEdin); D. Mair (Aberdeen); A. Sole (US); J. Wadham (BU)

This project is investigating the effect of surface generated melt-water fluctuations on ice motion at the margin of the Greenland Ice Sheet (GrIS). In particular, it is aimed at clarifying the relationship, over various time scales (daily to annual), between the input volume of surface

meltwaters and their effect on ice motion through consequent changes in basal sliding. The study is focused on ice motion and hydrology data collected along both land (Leverett Glacier) and ocean (Kangiata Nunata Sermia) terminating transects of the Greenland Ice Sheet to distances >100km from the ice margin. Ice motion is derived from differential GPS and hydrology includes information on surface melt rates and proglacial runoff with subglacial hydrology inferred from dye tracing and bulk meltwater parameters (electrical conductivity, turbidity and discharge). MODIS imagery is used to characterize the role of supraglacial lake drainage in driving the seasonal evolution of both the hydrology and subsequent glacier dynamics. An additional outcome from the research has been clarifying the importance of surface-derived meltwaters in driving high rates of erosion through the efficient evacuation of products of subglacial erosion. The work has been supported by the NERC, the University of Edinburgh Moss Scholarships and the Carnegie Trust for the Universities of Scotland. More information on publications and other outputs from the work are available at: http://www.geos.ed.ac.uk/glaciology/hydrology_dynamics
E-mail: Peter.Nienow@ed.ac.uk

The Vaigat Rock Avalanche and Tsunami Laboratory, Greenland
S. Dunning (UNN); N. Rosser, A. Long, E. Norman, J. Benamin (DU); W. Szczuciski, M. Strzelecki (UPP)
We are investigating a cluster of large landslides in Western Greenland, a number of which may have caused tsunamis. We aim to establish their temporal and spatial links to ice and sea level changes, and use them as a natural sensitivity analysis for numerical runout codes. During the summer of 2013 our primary objectives are: ground control support for a 900 km swath of LiDAR data collection (to be undertaken by NERC-ARSF); field mapping of deposits to understand terrestrial–subaqueous transitions; and the collection of rock samples for cosmogenic dating.
E-mail: Stuart.dunning@northumbria.ac.uk

Jökulhlaups from the Eyjafjallajökull eruption, Iceland
S. Dunning, J. Woodward, M. Lim (UNN); A.R.G. Large, A.J. Russell, A-S. Meriaux (NU); M.J. Roberts, (IMO); R. Duller (LivU); F.S. Tweed (StaffU).
We have integrated pre- and post-eruption terrestrial-laser scanning, in-event time-lapse imagery and downstream stage records to reconstruct the outbust floods associated with the 2010 subglacial eruption of Eyjafjallajökull. More than 140 discrete events deposited a total of 17 million cubic metres of sediment into the proglacial lake of Gigjökull, completely infilling it. We quantified the geomorphic signature of the events and show that peak sediment flux was not coupled with peak discharge during the two large outburst floods (57 x 10^6 m^3 water), and quantify the importance of a prolonged period of minor jökulhlaups in producing the current proglacial landscape.
E-mail: Stuart.dunning@northumbria.ac.uk

Modelling permafrost changes in the Arctic
Ruth Mugford, Poul Christoffersen and Julian Dowdeswell (CU)
We have applied GEOtop, which is a fully coupled thermal and hydrological model of subsurface permafrost soil, to investigate the evolution and decay of permafrost on the North Slope of Alaska. The suitability of using ERA-Interim reanalysis data to force GEOtop has been assessed and published in the *Proceedings of the Tenth International Conference on Permafrost*. We have compared ERA-Interim data to in situ observations of atmospheric parameters and assessed the ability of ERA-Interim to capture interannual and seasonal variability. GEOtop was used to model the thermal state of the subsurface in the Imnavait basin, Alaska, forced by ERA-Interim reanalysis data. Model results of soil temperature profiles were validated using borehole observations. This work demonstrates the feasibility of using atmospheric reanalysis products such as ERA-Interim to force the GEOtop model and therefore enables simulations to be performed in regions such as the Arctic where in situ meteorological measurements are sparse. A further validation of the GEOtop model forced by ERA-Interim data has been carried out in the Kuparuk basin, which has an area of approximately 9000 km^2. We investigated the main controls on changes in the soil temperature and active layer depth over the past 20 years.
E-mail: rm423@cam.ac.uk

Modelling iceberg-rafted sedimentation and melt in Greenland
Ruth Mugford and Julian Dowdeswell (CU)
A model, SedBerg, has been developed to simulate iceberg melt and sedimentation in high-latitude glaciated fjords and on the continental shelf (http://csdms.colorado.edu/wiki/Model:SedBerg). The model simulates the formation, drift, and melt of a population of icebergs utilizing Monte Carlo-based techniques with a number of underlying parametric probability distributions to describe the stochastic behaviour of iceberg formation and dynamics. Sediments deposited by icebergs provide an important record of glaciological response to changing climatic conditions. The model has been applied to Kangerdlugssuaq

Fjord in East Greenland to simulate sedimentation over the past 1500 years, encompassing the climatic intervals of the Medieval Warm Period (MWP) and the Little Ice Age (LIA). The model demonstrates that the glaciological regime (e.g. basal debris thickness, mean annual calving rate, mean iceberg size) plays a more important role than the direct influence of climate (ocean and air temperatures) on iceberg sedimentation rate, although often changes in climate result in changes to the glaciological regime (doi:10.1029/2009JF001564). Further research with SedBerg has involved modelling the distribution of freshwater inputs to the ocean due to iceberg melt in North East Greenland and predicting how this may change in the future.
E-mail: rm423@cam.ac.uk

TECHNIQUE DEVELOPMENT AND LABORATORY STUDIES

Airborne lidar to investigate glacier geomorphic processes

N. Arnold, I. Willis, C. Robb (CU), T. Johannesson (IMO), Finnur Pálsson (UI)

High-resolution remotely sensed data are increasingly being used in glaciology to map aspects of the landscape and quantify current environmental change. Such data are also used in glacial geomorphology to map landforms, infer processes of erosion/deposition and characterize past glacial conditions. As more data become available at increasingly higher spatial and temporal resolutions, there is a need to automate the process of landform and landscape mapping using objective, consistent and accurate computer-based object and pattern recognition techniques. This project uses a large airborne lidar data set, covering all the main ice caps, outlet glaciers and their fore fields, collected recently as part of a collaborative venture between SPRI, the Icelandic Meteorological Office and the University of Iceland. Algorithms are being developed and calibrated/evaluated against existing geomorphic maps and field evidence. A key output from the research will be a suite of glacier geomorphic maps for Iceland that can be used to identify spatial and temporal patterns of retreat, and of surge vs non-surge behaviour as well as important glacial geomorphic processes such as glacier tectonics, different styles of sediment deformation, subglacial hydrology and proglacial fluvial activity.
E-mail: nsa12@cam.ac.uk

Measuring avalanche dynamics to unprecedented resolution

Chris Keylock (US), Jim McElwaine (DU)

In collaboration with Matthew Ash and Paul Brennan at UCL, Nathalie Vriend at Cambridge and Betty Sovilla (SLF, Switzerland) we have developed and installed a radar for measuring avalanche dynamics at the avalanche test site at Vallée de la Sionne, Switzerland. Although a controlled experimental release has not been possible, we have recorded a number of avalanches where a geophone automatically triggered our radar imaging.

While existing radar were able to produce speed estimates averaged over a 25 m distance, it was not clear how to relate such information to point measurements in the path and this distance was too great to infer dynamical processes. Our new instrument averages over a 0.75 m distance and the data have been validated against point measurements from the mast in the avalanche path. We now hope to move forward and use these data to make progress inferring dynamical mechanisms.
E-mail: c.keylock@sheffield.ac.uk

Modelling glacial meltwater-plume dynamics and sedimentation in high-latitude fjords

Ruth Mugford and Julian Dowdeswell (CU)

A numerical model, SedPlume, has been developed to simulate deposition of suspended sediment from meltwater plumes emerging from tidewater-glacier margins. Turbid meltwater entering a fjord from a subglacial channel rises as a buoyant plume due to salinity and temperature contrasts with the fjord water. A model is formulated for the conservation equations of volume, momentum, buoyancy and sediment flux along the path of a turbulent plume injected into stratified marine water. Sedimentation occurs from the plume when the sediment fall velocity is greater than the entrainment velocity. Flocculation is modelled using empirical measurements of particle-settling velocities in fjords to adjust the settling velocity of fine-grained sediments. The SedPlume model has been applied to McBride Inlet in Alaska, with the results published in the *Journal of Geophysical Research* (doi:10.1029/2010JF001735). We are currently modelling sedimentation from plumes around Austfonna in Svalbard in conjunction with satellite observations and hydrological modelling of the ice cap.
E-mail: rm423@cam.ac.uk

Validation and Provision of CryoSat Measurements of Fluctuations in the Earth's Land Ice Fluxes

P. Nienow (UEdin); D. Mair (Aberdeen); S. de la Peña (BRYD); A. Sole (SU)

This research is linked to the 2010 launch of the European Space Agency's CryoSat-2 radar altimeter. In order to assess the errors in satellite altimeter measurements of surface elevation, it is vital to know whether the return is originating at the ice sheet surface or from some depth below the surface. The research, based on field experimentation from the percolation zone of the Greenland Ice Sheet, has demonstrated how temporal and spatial variations in the volume backscatter, due primarily to seasonal density variations in the snowpack/firn stratigraphy, can be a complicating factor in the radar return from the icesheet surface. We have also shown that CryoSat-2 has the potential to derive spatially extensive, ice-sheet-wide estimates of annual accumulation. The work has been supported by the UK NERC and the European Space Agency (ESA). More information on publications and other outputs from the work are available at: http://www.geos.ed.ac.uk/glaciology/cryosat

E-mail: Peter.Nienow@ed.ac.uk

Magnetic fabrics within basal ice

Edward Fleming, Ian Fairchild, Carl Stevenson, Emily McMillan (BhamU); Harold Lovell (QMUL); Michael Hambrey (AU); Doug Benn (UNIS); Michael Petronis (NHMU).

Strain within glacier ice can be difficult to analyse. In other areas of Earth science, however, one technique called AMS (Anisotropy of Magnetic Susceptibility) has been shown to provide considerable insight concerning the depositional and deformational histories of rock and sediment. AMS involves quantitative fabric characterization through the orientation of magnetic minerals. In this project, AMS is applied, for the first time to basal glacier ice from surge-type glaciers in Svalbard. The aims of this project are to determine the origin of magnetic fabrics within basal ice and determine its relationship with other visible strain indicators within the ice both at outcrop scale and through the analysis of aerial photographs. Through these investigations, the potential of the technique for the analysis of basal ice can be evaluated and future areas can be identified in which the technique can be explored.

E-mail: mjh@aber.ac.uk

MISCELLANEOUS

Glaciological investigations of glacier-like forms on Mars

Bryn Hubbard, Colin Souness, S. Brough (AU)

The individual position and morphometry of over 1300 glacier-like forms (GLFs) have been identified and catalogued on the surface of Mars. These GLFs are located throughout the planet's mid-latitudes between 25 and 65˚C, peaking at 40˚C, in both hemispheres. GLFs are preferentially located on poleward-facing slopes of both hemispheres, but there is little systematic control exerted by either local relief or elevation. Individually, GLF surfaces appear to be composed of several distinctive terrain types. The detailed interpretation of a single GLF on the basis of ~0.25 m resolution HiRISE imagery indicates that the current ice-rich body has receded within a larger basin, the lower zone of which is now largely composed of relict bedforms – possibly indicating former wet-based glacial conditions. Ongoing research is focusing on (i) reconstructing the 3D extent of former GLFs, (ii) investigating indicators of GLF flow and 3D strain, and (iii) developing a spatially distributed higher-order numerical model of GLF flow on Mars. All three will be used to inform understanding of GLF mass balance and mass-balance change on the surface of Mars.

E-mail: byh@aber.ac.uk

BRITICE-CHRONO; constraining rates and style of marine-influenced ice sheet decay.

Around 40 researchers are involved in a concerted effort on geochronometric dating to constrain and understand retreat of the last British–Irish Ice Sheet. The steering group comprises Chris Clark, James Scourse, Colm Ó Cofaigh, Richard Chiverell, Derek Fabel, and Richard Hindmarsh. Investigators include David Small, Matt Burke, Ian Rutt, Siwan Davies, Mark Bateman, Grant Bigg, Dave Evans, Dave Roberts, Geoff Duller, Mike Hambrey, Sara Benetti, Tom Bradwell, Steve Moreton, Stewart Freeman, Joana Gafeira, Danny McCarrol, Katrien van Landeghem, Anna Pienkowski and Colin Ballantyne. Our international advisory board of ice sheet modellers includes Richard Hindmarsh, Glen Milne, Dave Pollard, Catherine Ritz, Ian Rutt, Alun Hubbard, Gwen Flowers and Andreas Veili. A large group (NERC consortium project) will search the seafloor around Britain and Ireland and parts of the landmass in order to find and extract samples of sand, rock and organic matter that can be dated to reveal the timing and rate of change of the collapsing ice sheet that once covered the British Isles. The purpose is to produce a high -resolution dataset on the demise of an ice sheet

– from the continental shelf edge and across the marine to terrestrial transition. Some 800 new date assessments will be added to the 900 that already exist. Such data and reconstructions of ice retreat will be used and made freely available for ice-sheet modelling experiments whose ultimate aim is to improve forecasting of ice-volume changes in Antarctica and Greenland.
E-mail: C.clark@sheffield.ac.uk

Glacial hazard and risk minimization protocols
John M. Reynolds (Reynolds International Ltd)
The first international guidelines for the development of glacial hazard and risk minimization protocols in rural environments were published in 2013, funded by the UK Government's Department for International Development. The guidelines are currently available via www.reynolds-international.co.uk/dfid. Following further research in methods of glacial hazard assessment in the Himalayas, Tien Shan mountains and Patagonia, and detailed evaluation by Matt Westoby (Aberystwyth University) of Glacial Lake Outburst Flood modelling, the time has come for these guidelines to be updated and re-issued. As a contribution under the aegis of GAPHAZ, the Glacier and Permafrost Hazards in Mountains Scientific Working Group of the International Association of Cryospheric Sciences (IACS) and the International Permafrost Association (IPA), work is being undertaken to review, edit and update the guidelines with the intention of publishing the next edition in 2014.

Palaeoglaciology of the Welsh Ice Cap
John Balfour, Michael Hambrey, Neil Glasser, Bethan Davies, Jeremy Davies (AU), Philip Hughes (MancU)
The Welsh Ice Cap formed a peripheral accumulation area within the Late Devensian (=Late Weichselian) British–Irish Ice Sheet. Numerical modelling of this highly dynamic ice sheet suggests that flow was focused within ice streams. One major ice stream in Wales originated in the Cambrian Mountains and flowed down the Teifi Valley towards the south and west. To constrain the rates of recession of this ice stream a combination of geomorphological mapping, sedimentology, cosmogenic and luminescence dating, and coring is being applied to this area. Further north, cosmogenic dating to determine whether the highest mountains of Snowdonia projected above the ice sheet, or whether the ice was cold-based, is being undertaken.
E-mail: john.balfour@aber.ac.uk

Origin of foliation in glaciers and ice sheets
Stephen Jennings, Neil Glasser, Michael Hambrey, Tom Holt, Bryn Hubbard (AU)
Foliation is a ubiquitous surface feature in valley glaciers, but its relationship with folding and basal ice has not been fully defined. This project is examining the structural, crystallographic and isotopic composition of a number of valley glaciers in the Kongsfjorden area of Svalbard in order to define several foliation types and how these relate to folding and flow-unit boundaries. From this work, the analysis is being extended via remote sensing to Antarctic ice streams and flow stripes, where geometrically similar 'flow stripes' are well developed to test the hypothesis that these features are sometimes the surface manifestation of foliation.
E-mail: saj7@aber.ac.uk

Resolving the 'Snowball Earth' hypothesis in the polar North Atlantic
Ian Fairchild, Carl Stephenson, Edward Fleming, Emily McMillan (BhamU); Michael Hambrey (AU); Doug Benn (UNIS); Michael Petronis (NMHU)
The aim of this international project is to improve understanding of the nature of Earth-surface systems during extreme Neoproterozoic glaciations in NE Svalbard and NE Greenland, and to generate key data on the Cryogenian succession in the depositional basin to facilitate the choice of a global stratotype. The Neoproterozoic Era (1000–542 Ma) is famous for its ice ages, especially within the eponymous Cryogenian period (800–630 Ma). The Cryogenian glaciations appear to have been prolonged disturbances of the Earth System that were more severe than any subsequent perturbation. They have left a record of glacigenic sediments on all continents. Of these, Svalbard glacigenic sediments and associated carbonates are among the best preserved in the world. This project represents a renewed phase of work on these well exposed yet under-researched deposits to provide robust tests for the nature of the climate, environment, atmosphere and palaeogeography, using insights from state-of-the-art sedimentary, geochemical and magnetic techniques. Studies of modern polythermal and cold glaciers, and their associated marine, lacustrine and terrestrial settings, are proving to provide a range of analogues that explain the characteristics of the Neoproterozoic deposits. The team has undertaken two field campaigns in Ny Friesland, Svalbard and on Ella Ø in East Greenland, the data from which will help to answer some of the key questions concerning the Snowball Earth hypothesis and alternative more moderate scales of glaciation.
Email: mjh@aber.ac.uk

Simultaneous measurement of underwater and above-water shapes of pressure ridges using multibeam sonar and laser scanning.

Peter Wadhams, John Fletcher, Till Wagner, Nick Toberg, Hanu Singh, William Trossell

As part of our participation in the European Union SIDARUS and ACCESS projects, a field operation to simultaneously measure the surface and underside topography of pressure ridges was carried out between 9 and 21 July 2012 using MV *Arctic Sunrise*, provided by Greenpeace International. The underside was profiled by a Sea Bed AUV of Woods Hole Oceanographic Institution. The surface topography was obtained in high resolution by laser scanning. The ship started from Longyearbyen, where the AUV was calibrated and tested, on 10 July, and sailed to meet the ice edge in Fram Strait at a location (79‘32″ N, 0′40″ E) corresponding to a Radarsat quadpol retrieval expected on 14 July and ordered by the Norwegian Meteorological Institute (Nick Hughes) as part of their participation. The ship was in 50% concentration first-year (FY) and multi-year (MY) floes when it reached this position. Five floes were studied in the experiment. The first floe selected was a large, long MY floe carrying a classic triangular ridge, a low rolling hummock and a lot of rubble. The ship was moored to the floe, the ScanLAB operation carried out during the AUV deployment, and several cores and thickness holes drilled to obtain optimal co-registration between laser and AUV. Floe 2, in the same vicinity, was a stamukha, a very old isolated pressure ridge, covered in dirt and of considerable draft (28 m), which is a feature of the shelf seas north of Siberia. They are ridges that run aground and remain fast to the seabed through a summer when all the ice around them melts, leaving the stamukha as a grounded isolated island, which may remain for a number of years at a given site before lifting off through melt and joining the Arctic circulation, to emerge through Fram Strait as a real rarity. To our knowledge no stamukha has been studied before in this intense way, and once again we were able to obtain AUV multibeam mosaics of the underside and laser scans of the topside. Floe 3 had a well developed ridge complex on one edge of a very large (2 km) floe. The first AUV transit was successful, but a second mosaic resulted in the vehicle being carried into the centre of the floe through not having sufficient power to stem a strong relative current moving under the floe. The AUV was lost and could not be recovered despite a day of searching. Floes 4 and 5 were mapped only on the upper surface by the laser, with drilled and cored holes. Floe 4 was overflown at low level by the Polar 5 aircraft of the Alfred Wegener Institute equipped with an EM-31 electromagnetic ice thickness sensor.

Email: pw11@hermes.cam.ac.uk

Direct measurement of the calving response in a very large iceberg

Peter Wadhams

We are partners in a project by the US Office of Naval Research, Arctic Program, to study wave–ice interaction in the Beaufort Sea in order to determine the magnitude of a possible feedback mechanism, whereby enhanced summer sea ice retreat gives increased fetch and hence a Greenland-Sea-style marginal ice zone (MIZ) in the Beaufort Sea causing even faster ice melt and retreat. The main experiments in support of this project involve the deployment of some 30 satellite-tracked directional wave buoys on floes and in the water during 2013, with data collection continuing into 2014. Our UK partner in this project is the British Antarctic Survey (Jeremy Wilkinson); there are seven US partners. One aspect of the study is to measure and understand the mechanism of wave-induced fracture of large floes due to oscillating stress fields near the ice edge, and an opportunity to study this in the case of a very large iceberg was offered in July–August 2012 by the BBC as part of the filming of the programme *Operation Iceberg* (shown on BBC2 in November 2012). The iceberg, some 8 km square and 100 m thick, was a product of the Petermann Glacier, grounded off Baffin Island, and was visited using the chartered R/V *Neptune*. The Cambridge group was represented by Peter Wadhams and Till Wagner. Other UK scientists on board included Richard Bates (St Andrews University) and Keith Nicholls (BAS), doing sonar sidewall mapping and ice drilling respectively. A Waverider GP12 directional wave buoy was deployed in the ocean near the iceberg throughout the experiment, and recorded a persistent swell from the SE. An array of tiltmeters and GPS vertical movement sensors was placed on the berg near the edge. These recorded the berg response to the waves, and on one occasion a calving event occurred while the instruments were in place and being examined by Wadhams and Wagner. The berg gave a perceptible upward lunge as a piece some 800 m x 200 m, containing the instruments and the experimenters, broke off. The two possible mechanisms for this are flexural strain due to the incident swell, and an upward moment arm due to the creation of a wave cut around the berg edge followed by collapse of the unsupported above-water snow leaving a submerged ram intact. These two effects are being modelled.

Email: pw11@hermes.cam.ac.uk

Other projects and plans
Peter Wadhams
As well as the SIDARUS, ACCESS and MIZ projects we are involved in a study with the European Space Agency called SICCI Sea Ice and Climate Change Initiative), a study of the most effective way of mapping sea ice thickness and extent from space. Sea ice is seen as one of eleven essential climate variables (ECVs) for which comprehensive space mapping is possible. This involves comparison of submarine ice thickness data with CryoSat and other satellite retrievals; our main UK partner is University College London but this work has been severely affected by the tragic accidents to Seymour Laxon and Katharine Giles. The next stage in experimental wave buoy work is a test experiment to be carried out in July 2013 by our colleague Martin Doble (Ocean-Ice SARL, Villefranche) using the Norwegian *Griffon* hovercraft in Fram Strait.
Email: pw11@hermes.cam.ac.uk

MASS BALANCE AND ALBEDO

BRDF of snow and ice for calibration of satellites
Amelia Marks (RHUL), Corrado Fragiacomo (NIOG), Alasdair MacArthur (UEdin), Giuseppe Zibordi (IESI), Nigel Fox (NPLab), Martin King (RHUL)
Measurements of changes in global reflectance are needed in climate-change research and satellites allow reflectance measurements of the poles. Reflectance of natural surfaces is not isotropic: reflectance varies with viewing and illumination angle. Surface bidirectional reflectance distribution function (BRDF) measurements are required for satellite calibration at the ideal Dome C site, Antarctica, one of the eight reference standards recommended by the Committee on Earth Observation Satellites (CEOS). BRDF is a ratio of downwelling irradiance to upwelling radiance in a particular viewing and illumination direction, which is typically determined as a hemispherical directional reflectance factor (HDRF), where HDRF is a measure of surface reflectance in a given direction with respect to a reference standard, as illuminated with irradiance from a whole sky hemisphere. HDRF measurements were taken of Dome C snow surfaces during the summer season 2011/12 (and Ny Ålesund, Svalbard, 2013) using a Gonio Radio Spectrometer System (GRASS). GRASS comprises two semicircular frames orthogonal to each other forming a hemisphere over the target snow surface; multi-angular fibre-optics are mounted on the frames to look at the target with different azimuth/zenith angles. HDRF was measured by GRASS at nine sites along a 100 m transect at zenith angles from 0–60°, azimuth angles from 0–360° and wavelengths from 400–1700 nm. Measurements were taken within 4 hours of solar noon to limit changes in solar zenith angle. GRASS provided an alternative way to measure HDRF, when compared to previous Dome C measurements, as GRASS enables simultaneous measurements of the same snow surface at all zenith and azimuth angles, compared to previous Dome C measurements, which incrementally looked at different snow surfaces for each angle measured, and had a restricted azimuth and zenith angle range.
E-mail: Amelia.Marks.2006@live.rhul.ac.uk

The effect of black carbon on sea-ice reflectivity and light penetration.
Martin King, Amelia Marks and Chris Ball (RHUL)
Sea ice has been generated in 2000 L tanks at RHUL to record the penetration in and reflectance from sea ice at different temperature, wavelengths (UV–Visible) with different loadings of black carbon. The experiments are assessing the effect of black carbon on albedo of sea ice surfaces for global climate models. These experiments are supported by radiative-transfer calculations, some of which are available now http://dx.doi.org/10.5194/tcd-7-943-2013.

A synoptic approach to glacier-climate interactions
T.K.R. Matthews, R. Hodgkins, R.L. Wilby (LU), H. Björnsson, F. Pálsson, S. Guðmundsson (UI), P. Jansson (US).
This research uses synoptic weather categories, identified using ERA-Interim reanalysis data, to evaluate the association between large-scale atmospheric processes and glacier meteorology/ablation at Vestari Hagafellsjökull, Iceland, and Storglaciären, Sweden. Near-surface air temperature lapse rates on Vestari Hagafellsjökull are found to vary significantly between the different categories: the steepest lapse rates (large decrease in temperature with increased elevation) are observed in categories characterized by strong synoptic wind speeds; shallow lapse rates are observed during periods of warm, cloud-free weather. Integrating this information into a regression model forced with the reanalysis data results in ~38% of daily lapse rate variability being explained. This level of skill is sufficient to effect appreciable improvements in the accuracy of air temperatures extrapolated vertically over Vestari Hagafellsjökull. The relationship between air temperature and ablation is also observed to vary between the categories. We

find that, defining category-specific temperature-index model parameters (slopes and intercepts of temperature-ablation regression) improves the skill with which ablation is simulated at both the Swedish and Icelandic glaciers (up to a 14% improvement in explained variance). The implications of this are twofold: first, that the skill of temperature-index models can be improved without the need for additional data recorded in situ; and, second, that ablation is differentially sensitive to changes in air temperature between weather categories. This latter point challenges the assumption of static temperature sensitivities often applied in temperature-index simulations, and is regarded as an important consideration for ablation modelling in the context of climate change.
E-mail: T.K.R.Matthews@lboro.ac.uk

Using airborne lidar and multispectral data to investigate mass balance and albedo changes of Langjökull, Iceland

I. Willis, N. Arnold, G. Rees, A. Pope, E. Pope (CU) and F. Pálsson (UI).

Airborne lidar and multispectral data were collected over Iceland's second largest ice cap (~925 km^2) in 2007. Another campaign is planned for 2013. A DEM generated from the 2007 lidar data has been compared with others for 1997 (from dGPS) and 2004 (from SPOT) and used to investigate surface elevation changes and the geodetic mass balance across the ice cap and for its major outlet glaciers. Additionally, the ice cap's surface mass balance has been determined independently between 1997 and 2007 using a degree-day model, driven by daily gridded temperature and precipitation fields. For the major outlet glaciers, and for the ice cap as a whole, the geodetic balances are compared with the modelled balances for the epochs 1997–2004 and 2004–07, and the balance differences are used to derive patterns of vertical ice velocity due to flux divergence for the two epochs. The results show typical patterns of accumulation area submergence and ablation area emergence but there are major deviations from these patterns associated with glacier surge and quiescence. The 2007 airborne multispectral data have been processed using various atmospheric correction models and narrow- to broad-band algorithms to derive various estimates of surface albedo patterns across the ice cap at a 5 m spatial resolution. Similarly, lower resolution Landsat ETM+ (30 m) and MODIS (250 m) data have also been processed in different ways to derive various estimates of albedo patterns. The higher-resolution data are degraded to the scale of the lower-resolution data and the strengths of correlations are used to establish the best atmospheric correction models and narrow- to broad-band algorithms to use and to identify the biases that exist in the various data products.
E-mail: iw102@cam.ac.uk

Surface energy balance, meteorology and melt of debris-covered glaciers

Ben Brock, (UNN), Tim Reid (UEdin), Mark Cutler, Catriona Fyffe, Martin Kirkbride (Dundee); Claudio Smiraglia, Guglielmina Diolaiuti (UoM), Francesca Pellicciotti, Marco Carenzo (Zurich), Jean Pierre Fosson, Marco Vagliasindi (FMSC), Edoardo Cremonese, Fabrizio Diotri (V. D'Aosta)

This project aims to improve understanding of the melt response of debris-covered glaciers to climate forcing through detailed field measurements and model development, based primarily at Miage glacier, Italian Alps. Since 2005, we have monitored near-surface meteorology using AWSs, debris temperature profiles and melt during summer ablation seasons. An eddy-covariance system has now been installed, primarily to quantify latent heat fluxes between debris layers and the atmosphere. We developed a physical point energy-balance model for a debris layer, DEB-Model, which is forced solely by hourly meteorological data and is able to closely replicate measured sub-debris ice melt rates. DEB-Model has been integrated into distributed energy-balance models for Miage glacier and the partly debris-covered Upper Arolla glacier, Switzerland. A separate energy balance model was developed to calculate backwasting rates on exposed ice cliffs, and applied at the glacier-wide scale by identifying steep slopes in a high resolution DEM of Miage glacier.
E-mail: Benjamin.brock@northumbria.ac.uk

Energy balance and melt on ice-covered volcanoes in southern Chile

Ben Brock (UNN); Andrés Rivera, Flavia Burger (CECS); Javier Corripio (MeteoExploration), Aldo Montecinos (Universidad de Concepción)

We have been monitoring meteorological conditions and surface melt on Mocho-Choshuenco and Villarrica volcanoes in the Chilean Lake district, 38–42° S since 2004 to improve understanding of the response of glaciers in the region to recent climatic changes. Summer ablation rates are high and strongly influenced by the distribution of low-albedo, low-conductivity tephras, which reduce melt where they emerge as continuous covers, and enhance melt where they are windblown across bare snow and ice surfaces. Daily albedo images derived from a fixed camera on Villarrica Volcano were incorporated into a distributed glacier energy-balance model to successfully simulate spatial patterns of melt associated with variable

tephra distribution. Winter melt episodes are also a notable feature of this region. We have reconstructed a 50 year record of these events, based on a strong correspondence of glacier near-surface temperatures and daily atmospheric temperature soundings from the nearby Puerto Montt radiosonde.
E-mail: Benjamin.brock@northumbria.ac.uk

Dust Impacts on Glaciated Environments: DIOGENES
Maria Shahgedanova, Stanislav Kutuzov and Kevin White (ReadU)
DIOGENES is an interdisciplinary project addressing impacts of mineral aerosol (dust) on glaciers. The project is set in the Caucasus Mountains, Russia. The project has two sets of objectives. The first set deals with characterization of dust deposited on glaciers and its radiative properties. We aim to provide detailed characterization of dust including elemental composition and particle size distribution, and quantify sensitivity of glacier melt to dust deposition discriminating between locally produced and long-travelled dust. The second set deals with long-travelled desert dust. We aim to establish a record of long-travelled dust deposition events using samples collected from the shallow ice cores which we extract on Mt. Elbrus, above 5000 m a.s.l. Trends and key meteorological controls over long-travelled dust deposition are quantified and dust provenance is determined with a very high temporal (~hours) and spatial (~100 km) resolution. To achieve this resolution, in addition to standard methods employed in glaciology, we use satellite products designed to monitor dust in the atmosphere, including Meteosat Second Generation SEVIRI red-green-blue composite imagery, MODIS atmospheric optical depth fields, data from Data from the Cloud Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) mission and air mass trajectories derived using the HYSPLIT model. It is envisaged that the obtained data on desert dust deposition will serve as a useful proxy in climatic reconstructions and will help us to validate simulations of dust pathways by the climate models.
Email: m.shahgedanova@reading.ac.uk

MID- AND LOW-LATITUDE GLACIERS

Glacier hydrology in Langtang Khola, Nepal: lake formation and drainage on debris-covered glaciers
I. Willis, N Arnold, E. Miles (CU), F. Pellicciotti (ETH, Switzerland), D. Stumm (ICIMOD, Kathmandu)
As glaciers retreat in response to climate warming, substantial modifications occur to their patterns of meltwater production, hydrological routing and water storage/release, resulting in major changes to the hydrographs of glaciated basins. Although high-resolution glacierized catchment modelling has been applied successfully in, for example, the European Alps, Scandinavia and North America, far less attention has been applied to watersheds in the Himalayas, where basic climate and hydrological data are lacking, where logistical, political and cultural challenges are greater, and yet where some of the largest communities of people reliant on water from glacierized catchments live, and where vulnerability to changes in water supply is high. The overall aims of this project are to: (i) collect climate, glacier mass balance and hydrology data in the Langtang region of Nepal; (ii) analyse the back catalogue of satellite multispectral data for the region in order to measure past glaciological and hydrological attributes of the catchments; (iii) use the data in (i) and (ii) together with gridded climate reanalysis data for the past, to develop a high spatial (~100 m) and temporal (hourly) glacier mass balance/hydrology model for the region. The model will be capable of calculating the filling and draining of surface and ice marginal lakes, which pose a threat of sudden flooding in the region. Finally, the model will be run into the future to assess the likely changes to glacier mass balance and hydrology into the 21st century in response to projected climate change.
E-mail: iw102@cam.ac.uk

Seasonal snow cover in northern Norway
Wilfred Theakstone (MancU)
I am studying long-term variations of the winter snow cover in northern Norway. Data are analysed in relation to terrain, air temperature and synoptic conditions. Information about temporal and spatial variations is provided by the dates of the onset of the period of continuous cover at each site, together with its duration and the maximum snow depth. These are influenced by the North Atlantic Oscillation (NAO). In Nordland county, which spans the Arctic Circle, the winter snow cover was deep and prolonged in the early part of the 20th century, when stormy conditions were associated with positive values of the winter (DJF) NAO index. In the 1920s, as the index declined, snow depths decreased sharply. More recently, they have increased as the index has tended to become more positive. The start date and duration of the period of snow cover, which differs between low-lying stations and those at higher altitude, is influenced by the autumn (SON) NAO index. Cluster analysis of the trajectories of air masses to a site provides information about moisture sources and transport routes. The

relationship between the NAO index and winter precipitation at Tustervatn, one of the Nordland study sites, differs from that at Tasiilaq, southeast Greenland, which is at a similar latitude. The contrast reflects the locations of the two sites in relation to that of the Icelandic low.
E-mail: wilfred.theakstone@manchester.ac.uk

Hydrology of debris-covered Miage glacier

Ben Brock (UNN), Catriona Fyffe, Martin Kirkbride (Dundee), Tim Reid (UEdin) Jean Pierre Fosson, Marco Vagliasindi (FMSC)

During the 2010/11 ablation seasons we investigated the functioning of the hydrological system of debris-covered Miage glacier, Italian Alps, using a combination of dye tracing experiments, high-temporal-resolution measurements of surface velocity, and monitoring of runoff and water quality in the main proglacial stream. Our results suggest the concurrent operation of two distinct drainage systems: (i) an efficient channelized system routing meltwater from bare snow and ice surfaces located above the continuously debris-covered zone (CDCZ); and (ii) an inefficient distributed system beneath the CDCZ, characterized by delayed and dispersed dye return traces and relatively chemically enriched water, which occasionally connects with the channelized system. The extensive CDCZ at Miage glacier has the effect of damping the daily amplitude of the proglacial stream hydrograph and may also influence glacier dynamics through its modulation of subglacial water pressure.
E-mail**:** Benjamin.brock@northumbria.ac.uk

Satellite-based mapping of supraglacial debris thickness

Ben Brock (UNN), Lesley Foster, Mark Cutler (Dundee); Claudio Smiraglia, Guglielmina Diolaiuti, Claudia Mihalcea (UoM), Francesca Pellicciotti, Lene Petersen (Zurich), Simone Schauwecker, Mario Rohrer (Meteodat GmbH, Zürich), Nadine Salzmann, Christian Huggel (UoZ), Markus Stoffel (UoG), Anil Kulkarni (IISB), A.L. Ramanathan (JNU), Renoj Thayyen (WHRCJ)

Knowledge of the spatial distribution of supraglacial debris thickness is crucial for melt modelling of debris-covered glaciers. We are exploring the potential of thermal remote-sensing imagery to map debris thickness across glaciers, based on the dependence of debris-surface temperature on debris thickness under melting conditions. Two approaches have been applied: (i) using empirical relationships between debris thickness and surface temperature derived from field sample point measurements and (ii) a physically based calculation of the surface energy balance, which requires additional meteorological data either from the field or a model. The former approach requires further study to establish how empirical coefficients may be transferred between different glaciers and climatic zones. The physical approach works well on individual Alpine glaciers, but more research is required to distribute accurately input meteorological data and to overcome the problems of nonlinear temperature profiles in debris that experiences overnight freezing, e.g. the Hindu Kush–Himalaya, and variations in thermal conductivity associated with changing moisture conditions.
E-mail: Benjamin.brock@northumbria.ac.uk

Glacial hazard assessment for Eastern Nepal, Bhutan and the Northern Patagonian Icefield

John M. Reynolds (Reynolds International Ltd)

Glacial hazard assessments have been undertaken previously for Bhutan (1998–2002), eastern Nepal (1994–2012), and the Northern Patagonian Icefield (2010–13). Following further developments in understanding the physical processes involved in the formation and catastrophic drainage of glacial lakes, a revised methodology for assessing glacial hazards objectively using better defined parameters has been developed. Consequently, the revised Multi-Criteria Analysis methodology is being applied to re-assess the glacial hazards in Bhutan, eastern Nepal and around the Northern Patagonian Icefield in Chile. The results of these re-assessments are due for publication in 2014.

BIOGEOCHEMISTRY

Ecology and biogeochemistry of glacial snowpacks

Andy Hodson, Krystyna Koziol (US); Marie Sabacká**,** David Pearce (BAS); James Chong, Kelly Redeker (UoY)

The nutrient budget and microbial ecology of melting snowpacks are under in situ investigation in the maritime Antarctic and European High Arctic. Particular emphasis is being given to (i) links between microbial ecology, snowmelt and the transfer of nutrients to polar coastal waters, (ii) the implications of significant, long-term microbial activity for ice core trace gas concentrations, and (iii) the global biogeochemical cycling of halogens, sulphur and trace metals in glacial snowpacks. We are collectively using a suite of methods to measure fluxes of water, nutrients, and low-level trace gases in the field, and then employing next-generation sequencing technologies and PLFA analyses to explore in situ metabolism of microbial populations. In so doing, we seek to understand the impact and drivers of

heterogeneity within the snow/ice matrix, e.g. within superimposed ice following meltwater refreezing, within the snow matrix following dust deposition and at the snow surface following summertime atmospheric nitrogen deposition. Major differences have been found in snow pack biogeochemistry and snow-bound microbial communities.
E-mail: A.J.Hodson@Sheffield.ac.uk

Biogeochemistry and microbiology of winter runoff from Svalbard glaciers
Aga Nowak, Andy Hodson (US)
Fine reactive sediments produced by glacial erosion sustain microbial habitats in subglacial, ice marginal and other sedimentary environments. Therefore, it is not surprising that microbially mediated rock–water interactions dominate the anionic composition of glacial meltwaters and acquire nutrients with the capacity to fertilize downstream ecosystems. However, those processes are difficult to detect when glacier surface melting strongly reduces the signal-to-noise ratio found in runoff samples. Therefore, to identify those processes, to evaluate microbially mediated production and also to classify microbial communities, we have been sampling subglacial waters and icings from multiple Svalbard glaciers during the pre-melt and late summer seasons. In so doing, we have also developed redox-sensitive, groundwater sampling techniques suitable for air temperatures as low as –30°C. Our results reveal weathering environments characterized by low redox processes (iron and sulphate reduction, methanogenesis) that are barely detectable in summer runoff. We have also found that the icings formed when these springs discharge into the proglacial environment during winter are active ecosystems regardless of the season. Furthermore, heterogeneity in microbial communities existing on and within the icings was discovered. Greater abundance of microorganisms was observed in the upper and lowermost parts of the icings, yet not all icings were the same because major variations in the microbial community structure were found from one icing to another. In some cases a significant autotrophic community was fertilized by high concentrations of iron and ammonium, resulting in the development of distinct microbial mats.
E-mail: A.J.Hodson@Sheffield.ac.uk

Arctic glacier surface ecology
A. Edwards, T. Irvine-Fynn, S. Rassner (AU), N. Takeuchi (CUJ)
We are investigating the spatial and temporal variability in glacier surface ecology, developing from well-known and described sites in NW Svalbard. Our approach is to combine a suite of glaciological and biological techniques to improve understanding of the ice–surface ecosystem. During summer 2013, our 4-week field campaign will target a minimum of five land-terminating valley glaciers in the Kongsfjord region. We will look to using flow cytometry (FCM) to enumerate and discriminate microbial cells in glacier meltwater, cryoconite forms, and shallow near-surface ice cores. Abstraction of samples will enable laboratory-based and molecular analyses, building up pictures of organic carbon content, productivity, microbial communities and their variability, and we aim to extend this to understand functionality through metagenomics. Previous spatially and temporally limited observations have suggested coupling between physical and biological characteristics, and so the sequence of biological observations will be augmented by glaciological observations using short-range photogrammetry, spectrometry, and hydrological tracer and chemical experiments, which will constrain the local environmental parameters. The work builds on the earlier UK–Japanese partnership developed through a Sasakawa Foundation Grant (in 2011), and our goal is to deepen comprehension of the supraglacial ecosystem.
E-mail: tdi@aber.ac.uk

Photochemistry in snow and sea ice
Martin King (RHUL)
Field (Barrow, Alaska) and modelling studies continue to calculate the production rates of highly chemically reactive species in sunlit snow and sea ice that make these environments highly efficient oxidizing environments abiotically. The oxidation chemistry produces fluxes of reactive gases to the overlying atmosphere and alters chemical loadings of species in the top of snow and sea ice.
E-mail: M.King@rhul.ac.uk

ABBREVIATIONS

ANU: Australian National University
AU: Aberystwyth University
BAS: British Antarctic Survey
BhamU: Birmingham University
BRYD: Byrd Polar Research Center, The Ohio State University, USA
BU: Bristol University
CCNY: City College, New York
CECS: Centro de Estudios Científicos
CU: Cambridge University
CUJ: Chiba University, Japan
DMI: Danish Meteorological Institute
DU: Durham University
FMSC: Fondazione Montagna Sicura, Courmayeur
IESI: Institute for Environment and Sustainability, Ispra, Italy
IISB: Indian Institute of Science, Bangalore
IMO: Icelandic Meteorological Office
JNU: Jawaharlal Nehru University
NIGL: NERC Isotope Geosciences Laboratory, Keyworth
NIOG: National Institute of Oceanography and Geophysics
NMHU: New Mexico Highlands University, USA
NPLAB: National Physical Laboratory, Hampton Road, Teddington
NU: Newcastle University
OU: Open University
QMUL: Queen Mary, University of London
ReadU: Reading University
RHUL: Royal Holloway University London
Scripps: Scripps Institute of Oceanography
StaffU: Staffordshire University
UChi: University of Chicago
UEdin: University of Edinburgh
UI: University of Iceland
ULB: Université Libre de Bruxelles
ULeeds: University of Leeds
UNIS: University Centre in Svalbard, Norway
UNN: University of Northumbria
UoG: University of Geneva
UoM: University of Milan
UoY: University of York
UoZ: University of Zurich
UPP: Adam Mickiewicz University, Poznan, Poland
US: University of Sheffield
USwan: Swansea University
V. D'Aosta: Agenzia Regionale per la Protezione dell'Ambiente della Valle d'Aosta
WHRCJ: Western Himalayan Regional centre, Jammu
Zurich: Swiss Federal Institute of Technology, Zürich

Bryn Hubbard

International Glaciological Society

JOURNAL OF GLACIOLOGY

Papers accepted for publication between 1 January and 30 June 2013. The papers are listed in alphabetical order by first author. Some of these papers have already been published.

Anthony Arendt, Scott Luthcke, Alex Gardner, Shad O'Neel, David Hill, Geir Moholdt, Waleed Abdalati
Analysis of a GRACE global mascon solution for Gulf of Alaska Glaciers

Argha Banerjee, R. Shankar
On the response of Himalayan glaciers to climate change

Nicholas E. Barrand, Richard C.A. Hindmarsh, Robert J. Arthern, C. Rosie Williams, Jérémie Mouginot, Bernd Scheuchl, E. Rignot, Stefan R.M. Ligtenberg, Michiel R. van den Broeke, Tamsin L. Edwards, Alison J. Cook, Sebastian B. Simonsen
Computing the volume response of the Antarctic Peninsula ice sheet to warming scenarios to 2200

Verena Bendel, Kai J. Ueltzhöffer, Johannes Freitag, Sepp Kipfstuhl, Werner F. Kuhs, Christoph S. Garbe, Sérgio H. Faria
High-resolution variations in size, number and arrangement of air bubbles in the EPICA DML ice core

Peter Bezeau, Martin J. Sharp, David O. Burgess, Gabrielle Gascon
Firn profile changes in response to extreme 21st century melting at Devon Ice Cap, Nunavut, Canada

Robert A. Bindschadler, Sophie Nowicki, Ayako Abe-Ouchi, Andy Aschwanden, Hyeungu Choi, Jim Fastook, Glen Granzow, Ralf Greve, Gail Gutowski, Ute Herzfeld, Charles Jackson, Jesse Johnson, Constantine Khroulev, Anders Levermann, William H. Lipscomb, Maria A. Martin, Mathieu Morlighem, Byron R. Parizek, David Pollard, Stephen F. Price, Diandong Ren, Fuyuki Saito, Tatsuru Sato, Hakime Seddik, Helene Seroussi, Kunio Takahashi, Ryan Walker, Wei Li Wang
Ice-sheet model sensitivities to environmental forcing and their use in projecting future sea-level (the SeaRISE Project)

Gauthier Carnat, Timothy Papakyriakou, N.X. Geilfus, Frédéric Brabant, B. Delille, Martin Vancoppenolle, Gaelle Gilson, Jiayun Zhou, Jean-Louis Tison
Investigations on Arctic first-year sea ice physical and textural properties in the Amundsen Gulf from November 2007 until June 2008

Luke Copland, Tyler Sylvestre, Michael N. Demuth, Martin J. Sharp
Spacial patterns of snow accumulation across Belcher Glacier, Devon Ice Cap

Kristopher Darnell, Jason M. Amundson, L. Mac Cathles, Douglas R. MacAyeal
The morphology of supraglacial lake ogives

Jeffrey S. Deems, Thomas H. Painter, David C. Finnegan
Lidar measurement of snow depth: a review

D. Dobhal, Manish Mehta, Deepak Srivastava
Influence of debris cover on terminus retreat and volume changes of Chorabari Glacier, Garhwal region Central Himalaya, India

Daniel Farinotti
On the effect of short-term climate variability on mountain glaciers – insights from a case study

Andrew A.W. Fitzpatrick, Alun Hubbard, Ian R. Joughin, Duncan J. Quincey, Dirk van As, Andreas P.B. Mikkelsen, Samuel H. Doyle, Bent Hasholt, Glenn A. Jones
Ice flow dynamics and surface meltwater flux at a land-terminating sector of the Greenland ice sheet

Johannes Freitag, Sepp Kipfstuhl, Thomas Laepple
Core-scale radioscopic imagine: a new method reveals density–calcium link in Antarctic firn

Johan Gaume, Guillaume Chambon, Nicolas Eckert, Mohamed Naaim
Influence of weak-layer heterogeneity on snow slab avalanche release: application to the evaluation of avalanche release depths

F. Gauthier, M. Montagnat, J. Weiss, M. Allard, B. Hétu
Ice cascade growth and decay: a thermodynamic approach

Heiko Goelzer, Philippe Huybrechts, J.J. Furst, Faezeh M. Nick, Morten L. Andersen, T.L. Edwards, X. Fettweis, Antony J. Payne, S. Shannon
Sensitivity of Greenland ice sheet projections to model formulations

Wolfgang Gurgiser, Thomas Mölg, Lindsey Nicholson, Georg Kaser
Mass-balance model parameter transferability on a tropical glacier

Pascal Hagenmuller, Guillaume Chambon, Bernard Lesaffre, Frederic Flin, Mohamed Naaim
Energy-based binary segmentation of snow microtomographic images

William D. Harrison
How do glaciers respond to climate: perspectives from the simplest models

Robert L. Hawley, Ola Brandt, Thorben Dunse, Jon Ove Hagen, Veit Helm, Jack Kohler, Kirsty Langley, Eirik Malnes, Kjell-Arild Høgda
Using airborne Ku-band altimeter waveforms to investigate winter accumulation and glacier facies on Austfonna, Svalbard

Kenneth G. Hughes, Pat J. Langhorne, Michael J.M. Williams
Estimates of the refreezing rate in an ice shelf borehole

Mariam Jaber, Heinz Blatter, Marco Picasso
Measurement of strain rate components in a glacier with embedded inclinometers: numerical analysis

Austin J. Johnson, Christopher F. Larsen, Nathaniel Murphy, Anthony A. Arendt, S. Lee Zirnheld
Mass balance in the Glacier Bay area of Alaska, USA, and British Columbia, Canada, 1995–2011, using airborne laser altimetry

Christian Keinholz, Regine Hock, Anthony Arendt
A new semi-automatic approach for dividing glacier complexes into individual glaciers

Jonathan Kingslake, Felix S.L. Ng
Quantifying the predictability of the timing of jökulhlaups from Merzbacher Lake, Kyrgyzstan

T.M. Kyrke-Smith, R.F. Katz, A.C. Fowler
Stress balances of ice streams in a vertically integrated, higher-order formulation

J.F. Levinsen, I.M. Howat, C.C. Tscherning
Improving maps of ice sheet surface elevation change using combined laser altimeter and stereoscopic elevation model data

Liz Logan, Ginny Catania, Luc Lavier, Eunseo Choi
A novel method for predicting fracture in floating ice

Scott B. Luthcke, T.J. Sabaka, B.D. Loomis, A.A. Arendt, J.J. McCarthy, J. Camp
Antarctica, Greenland and Gulf of Alaska land ice evolution from an iterated GRACE global mascon solution

Joseph A. MacGregor, Ginny A. Catania, Howard Conway, Dustin M. Schroeder, Ian Joughin, Duncan A. Young, Scott D. Kempf, Donald D. Blankenship
Weak bed control of the eastern shear margin of Thwaites Glacier

D.M. McClung
The effects of El Niño and La Niña on snow and avalanche patterns in British Columbia, Canada, and central Chile

Nikolai Mel'nichenko, A.B. Slobodyuk
Nuclear magnetic resonance study of sea-water freezing mechanisms: 1. Temperature dependence of relative brine content in sea ice

Nikolai Mel'nichenko
Nuclear magnetic resonance study of sea-water freezing mechanisms: 2. Temperature dependence of relaxation time on protons in sea-ice brine

Sebastian H. Mernild, Niels T. Knudsen, Matthew Hoffman, Jacob C. Yde, Edward Hanna, William H. Lipscomb, Jeppe K. Malmros, Robert S. Fausto
Volume and velocity changes at Mittivakkat Gletscher, southeast Greenland, 1994–2012

Sebastian H. Mernild, Mauri Pelto, Jeppe K. Malmros, Jacob C. Yde, Niels T. Knudsen, Edward Hanna
Identification of snow ablation rate, ELA, AAR and net mass balance using transient snowline variations on two Arctic glaciers

Mohamed Naaim, Yves Durand, Nicolas Eckert, Guillaume Chambon
Dense avalanche friction coefficients: influence of physical properties of snow

Frank Pattyn, Laura Perichon, Gaël Durand, Lionel Favier, Olivier Gagliardini, Richard C.A. Hindmarsh, Thomas Zwinger, Torsten Albrecht, Stephen Cornford, David Docquier, Johannes J. Fürst, Daniel Goldberg, G. Hilmar Gudmundsson, Angelika Humbert, Moritz Hütten, Philippe Huybrechts, Guillaume Jouvet, Thomas Kleiner, Eric Larour, Daniel Martin, Mathieu Morlighem, Anthony J. Payne, David Pollard, Martin Rückamp, Oleg Rybak, Hélène Seroussi, Malte Thoma, Nina Wilkens
Grounding-line migration in plan-view marine ice-sheet models: results of the ice2sea MISMIP3d intercomparison

A. Richter, D.V. Federov, M. Fritsche, S.V. Popov, V.Ya Lipenkov, A.A. Ekaykin, V.V. Lukin, A.Yu. Matveev, V.P. Grebnev, R. Rosenau, R. Dietrich
Ice flow velocities over subglacial Lake Vostok, East Antarctica, determined by 10 years of GNSS observations

David Rippin
Bed roughness beneath the Greenland ice sheet

Kristin M. Schild, Gordon S. Hamilton
Seasonal variations of outlet glacier terminus position in Greenland

Sebastian B. Simonsen, Lars Stenseng, Guðfinna Aðalgeirsdóttir, Robert S. Fausto, Christine S. Hvidberg, Philippe Lucas-Picher
A multilayered dynamic firn-compaction model for Greenland with ASIRAS radar measurements

A.V. Sundal, A. Shepherd, M. van den Broeke, J. Van Angelen, N. Gourmelen, J. Park
Controls on short-term variations in Greenland glacier dynamics

Christina Tennant, Brian Menounos
Glacier change of the Columbia Icefield, Canadian Rocky Mountains, 1919–2009

Robert H. Thomas, Bernd Scheuchl, Earl Frederick, R. Harpold, Chreston Martin, Eric Rignot
Continued slowing of the Ross Ice Shelf and thickening of West Antarctic ice streams

Takenobu Toyota, Inga J Smith, Alexander J. Gough, Patricia J. Langhorne, Gregory H. Leonard, Robert J. van Hale, Andrew R. Mahoney, Timothy G. Haskell
Oxygen isotope fractionation during the freezing of seawater

Shun Tsutaki, Shin Sugiyama, Daisuke Nishimura, Martin Funk
Acceleration and flotation of a glacier terminus during a proglacial lake formation in Rhonegletscher, Switzerland

S.W. Tyler, D.M. Holland, V. Zagorodnov, A.A. Stern, C. Sladek, S. Kobs, S. White, F. Suárez, J. Bryenton
Using distributed temperature sensors to monitor an Antarctic ice shelf and sub-ice-shelf cavity

E. Warming, A. Svensson, P. Vallelonga, M. Bigler
A technique for continuous detection of drill liquid in ice cores

Roland C. Warner, Jason L. Roberts
Pine Island Glacier velocities from Landsat7 images between 2001 and 2011: FFT-based image correlation for images with data gaps

Ping Yao, Valérie F. Schwab, Vanessa-Nina Roth, Baiqing Xu, Tandong Yao, Gerd Gleixner
Levoglucosan concentration in ice-core samples from the Tibetan Plateau determined by reserve-phase high-performance liquid chromatography–mass spectrometry

Tong Zhang, Cunde Xiao, William Colgan, Xiang Qin, Wentao Du, Weijun Sun, Yushuo Liu, Minghu Ding
Observed and modelled ice temperature and velocity along the main flowline of East Rongbuk Glacier, Qomolangma (Mount Everest), Himalaya

ANNALS OF GLACIOLOGY 54(62)

The following papers have been selected for publication in Annals of Glaciology *53(62) (thematic issue on Seasonal snow and ice), edited by Matti Leppäranta*

Rajeev Saran Ahluwalia, S.P. Rai, Sanjay K. Jain, Bhishm Kumar, D.P. Dobhal
Assessment of snowmelt runoff modelling andisotope approach: a case study from the western Himalaya, India

Yoshihiro Asaoka, Yuji Kominami
Incorporation of satellite-derived snow-cover area in spatial snowmelt modeling for a large area: determination of a gridded degree-day factor

James Foster, Judah Cohen, David A. Robinson, Tom Estilow
A look at the date of snowmelt and correlations with the Arctic Oscillation

Jari Haapala, Mikko Lensu, Marie Dumont, Angelika H.H. Renner, Mats A. Granskog, Sebastian Gerland
Small scale horizontal variability of snow, sea ice thickness and freeboard in the first year ice region north of Svalbard

Shinji Ikeda, Tomoyuki Noro
Regional characteristics of snowpacks related to avalanches in the central mountains of Japan

Mikko Lensu, Bruce C. Elder, Jackie Richter-Menge, Jari Haapala
Comparison of ice stress records in terms of extreme value analysis

Lantao Li, Wei Gu, Chengyu Liu, Yingjun Xu, Jinlong Chao, Ying Li
Suitability of locations in the Bohai Sea, China, for the exploitation of sea ice as a fresh water resource

Kjetil Melvold, Thomas Skaugen
Multiscale spatial variability of Lidar-derived and modelled snow depth at Hardangervidda Mountain, Norway

Simon Prinsenberg, I.K. Peterson, J. Scott Holladay, Ryan J. Galley, Shannon Nudds
Atmospheric control of sea ice thickness variability in the Amundsen Gulf, Canadian Beaufort Sea, and over the Labrador Shelf

Markku Similä, Marko Mäkynen, Bin Cheng, Eero Rinne
Multisensor data and thermodynamic sea ice model based sea ice thickness chart with application to the Kara Sea

Satoru Yamaguchi, Katsushi Iwamoto, Sento Nakai
Interannual fluctuations of the relationship between winter precipitation and air temperature in the heavy snowfall zone of Japan

Inga Zaitseva-Pärnaste, Tarmo Soomere
Interannual variations of ice cover and wave energy flux in the northeastern Baltic Sea

Annals 54(62) is now complete

ANNALS OF GLACIOLOGY 54(63)

The following paper has been selected for publication in Annals of Glaciology *54(63) (thematic issue on Glaciers and ice sheets in a warming climate), edited by Gwenn Flowers*

Ralf Greve, Ute C. Herzfeld
Resolution of ice streams and outlet glaciers in large-scale simulations of the Greenland Ice Sheet

Annals 54(63) is now complete

ANNALS OF GLACIOLOGY 54(64)

The following papers have been selected for publication in Annals of Glaciology *54(64) (thematic issue on The geophysics of the cryosphere and glacier products), edited by Bernd Kulessa*

John H. Bradford, Joshua D. Nichols
Compressional and EM wave velocity anisotropy in a temperate glacier due to basal crevasses and implications for water content estimation

Anja Diez, Olaf Eisen, Coen Hofstede, Pascal Bohleber, Ulrich Polom
Joint interpretation of explosive and vibroseismic surveys on cold firn for the investigation of ice properties

C.F. Dow, A. Hubbard, A.D. Booth, S.H. Doyle, A. Gusmeroli, B. Kulessa
Seismic evidence of mechanically-weak sediments underlying Russell Glacier, West Greenland

Andrea Fischer, Michael Kuhn
Ground penetrating radar measurements of 64 Austrian glaciers between 1995 and 2010

Alessio Gusmeroli, Anthony Arendt, Donald Atwood, Bert Kampes, Mark Sanford, Joanna Young
Variable penetration depth of interferometric synthetic-aperture radar signals in Alaska glaciers: a cold surface layer hypothesis

Alessio Gusmeroli, Tavi Murray, Roger A. Clark, Bernd Kulessa, Peter Jansson
Vertical seismic profiling of glaciers: appraising multi-phase mixing models

Sophie Harland, J. Michael Kendall, Graham Stuart, Geoff Lloyd, A.F. Baird, Andrew Smith, Hamish Pritchard, Alex Brisbourne
Deformation in the Rutford ice stream, West Antarctica: measuring shear-wave anisotropy using icequakes

Coen Hofstede, Olaf Eisen, Anja Diez, Daniela Jansen, Yngve Kristoffersen, Astrid Lambrecht, Christoph Mayer
Investigating englacial reflections with vibro- and explosive-seismics surveys at Halvfarryggen ice dome, Antarctica

Ben Lishman, Jemma Wadham, Bruce Drinkwater, J.-Michael Kendall, Steve Burrow, Geoff Hilton, Ian Craddock
Assessing the utility of acoustic communications for wireless sensors deployed beneath ice sheets

Alba Martín-Español, Evgeny V. Vasilenko, Francisco J. Navarro, Jaime Otero, Javier J. Lapazaran-Izargain, Ivan Lavrentiev, Yuri Ya. Macheret, F. Machío
Radio-echo sounding and ice volume estimates of western Nordenskiöld Land glaciers, Svalbard

Sébastien Monnier, Christophe Kinnard
Internal structure and composition of a rock glacier in the Andes (upper Choapa Valley, Chile) using borehole information and ground-penetrating radar

Felix Ng, Edward C. King
Formation of RADARSAT backscatter feature and undulating firn stratigraphy at an ice-stream margin

Aiden A. Parkes, Ian G. Stimpson, Richard I. Waller
Geophysical surveying to determine origin and structure of the Woore Moraine, Shropshire, UK

Joseph Pomeroy, Alex Brisbourne, Jeffrey Evans, David J Graham
The search for seismic signatures of movement at the glacier bed in a polythermal valley glacier

Daniel Steinhage, Sepp Kipfstuhl, Uwe Nixdorf, Heinz Miller
Internal structure of the ice sheet between Kohnen station and Dome Fuji revealed by airborne radio-echo sounding

Shin Sugiyama, Kotaro Fukui, Koji Fujita, Kenta Tone, Satoru Yamaguchi
Changes in ice thickness and flow velocity of Yala Glacier, Langtang Himal in Nepal, from 1982 to 2009

Donald Voigt, Leo E. Peters, Sridhar Anandakrishnan
'Georods': the development of a four-element geophone for improved seismic imaging of glaciers and ice sheetsBering Glacier surge 2011: analysis of laser altimeter data

Ute C. Herzfeld, Brian McDonald, Alexander Weltman
Bering Glacier and Bagley Ice Valley surge 2011: crevasse classification as an approach to map deformation stages and surge progression

Martin Heynen, Francesca Pellicciotti, Marco Carenzo
Parameter sensitivity of a distributed enhanced temperature-index melt model

Andreas Linsbauer, Frank Paul, Horst Machguth, Wilfried Haeberli
Comparing three different methods of modelling scenarios of future glacier change in the Swiss Alps

Clément Miège, Richard R. Forster, Jason E. Box, Evan W. Burgess, Joseph R. McConnell, Daniel R. Pasteris, Vandy B. Spikes
Southeast Greenland high accumulation rates derived from firn cores and ground-penetrating radar

Marco Möller, Roman Finkelnburg, Matthias Braun, Dieter Scherer, Christoph Schneider
Variability of the climatic mass balance of Vestfonna ice cap (northeastern Svalbard) in the period 1979–2011

Torbjørn I. Østby, Thomas V. Schuler, Jon Ove Hagen, C.H. Reijmer, Regine Hock
Parameter uncertainty, refreezing and surface energy balance modelling at Austfonna ice cap, Svalbard, over 2004–2008

F. Paul, N.E. Barrand, S. Baumann, E. Berthier, T. Bolch, K. Casey, H. Frey, S.P. Joshi, V. Konovalov, R. Le Bris, N. Mölg, G. Nosenko, C. Nuth, A. Pope, A. Racoviteanu, P. Rastner, B. Raup, K. Scharrer, S. Steffen, S. Winsvold
On the accuracy of glacier outlines derived from remote sensing data

Lene Petersen, Francesca Pellicciotti, Inge Juszak, Marco Carenzo, Benjamin W. Brock
Suitability of a constant air temperature lapse rate over an Alpine glacier: testing the Greuell and Böhm model as an alternative

L. A. Rasmussen
Meteorological controls on glacier mass balance in High Asia

C.A. Reese, K.B. Liu, Lonnie G. Thompson
An ice-core pollen record showing vegetation response to late-glacial and Holocene climate changes at Nevado Sajama, Bolivia

Rafael da Rocha Ribeiro, Edson Ramirez Rodriguez, Jefferson Cardia Simões, Abraham Machaca
Forty-six years of environmental records from the Nevado Illimani lacier group, Bolivia, using digital photogrammetry

Annals 54(64) is now complete

Books received

J. Brown and 19 others (2012) *State of the Earth's cryosphere at the beginning of the 21st century: glaciers, global snow cover, floating ice, and permafrost and periglacial environments.* In WIlliams RS Jr and Ferrigno JG eds. Satellite image atlas of glaciers of the world. (USGS Professional Paper 1386-A) United States Geological Survey, Denver, CO

M. Husse, J. Redfern, D.P. Le Heron, R.J. Dixon, A. Moscariello and J. Craig, eds. *Glaciogenic Reservoirs and Hydrocarbon Systems.* Geological Society (Special Publication 368), London. 401 pages. ISBN: 978-1-86239-348-6 (cloth), List price £120/$240.

O Sigursson and R.S. Williams Jr (2008) *Geographic names of Iceland's glaciers: historic and modern.* (USGS Professional Paper 1746) United States Geological Survey, Reston, VA

Meetings of other societies

Symposium: 50 Years of Glacier Research

Bavarian Academy of Sciences, Munich, Germany, 14–15 March 2013

Audience hall (from left to right): Heinz Miller, Martin Kuhn, Roger Braithwaite, Atsumo Ohmura

Entrance hall: Roger Braithwaite, Magnús Magnússon, Oskar Reinwarth, Atsumo Ohmura

The Commission for Glaciology was founded in 1962 at the initiative of Professor Richard Finsterwalder and Professor Herfried Hoinkes, among others, to investigate the relationship between climate variations and glacier behavior. The focus of research has been concentrated in the Vernagtferner area of Austria, where various methods of glacier mass balance determinations have been applied. To commemorate 50 years of monitoring and research efforts, a symposium was held in the Bavarian Academy of Sciences in Munich. About 250 participants followed the welcoming speech of Magnús M. Magnússon, Secretary General of the International Glaciological Society, who pointed out the value of long-term observations and research in glaciology. Heinz Miller (Bremerhaven) showed the relevance of alpine and polar glacier research in the current climate change debate, and Atsumu Ohmura (Zürich) discussed the impact of global dimming and brightening in determining the glacier mass balance. Heidi Escher-Vetter (Munich) reported on the methods of meteorological and glaciological methods as they changed through time and gave an analysis of the data gathered up to now. Markus Weber (Munich) provided an overview of photographic monitoring of Vernagtferner, including currently unpublished photos of the glacier surge around 1900. The first day of the symposium ended with a poster session showing the broad range of current research projects

Entrance hall: Atsumo Ohmura, Roger Braithwaite, Magnús Magnússon

Heinz Miller giving his lecture

The symposium's hosts: Prof. Dr K.H. Hoffmann, President of the Bavarian Academy of Sciences and Humanities, and Prof. Dr R. Rummel, President of the Commission for Geodesy and Glaciology

Christoph Mayer and Prof. Dr Bunge, Vice President of the Commission for Geodesy and Glaciology

Dinner in a traditional Bavarian restaurant (Spoeckmeier) (from left to right): Martin Kuhn, Atsumo Ohmura, Peter and Heidi Escher-Vetter, Roger Braithwaite, Magnús M. Magnússon

At dinner in traditional Bavarian restaurant: Martin Hoelzle, Dietmar Wagenbach, Olaf Eisen, Martin Zemp

of the Commission for Geodesy and Glaciology, as the Commission was renamed in 2011, followed by a festive dinner in a traditional Bavarian restaurant.

The second day started with contributions from Ludwig Braun and Christoph Mayer (Munich) on the relevance of glacier meltwater in larger river basins and the dynamics of glacier movement. Christof Völksen and Christian Gerlach (Munich) reported on their geodetic research efforts in glaciological research, and the current president of the Commission, Professor Reiner Rummel (Munich), gave a scientific perspective on monitoring and research, combining classical glaciological and geodetic satellite-based approaches.

The many achievements of the past 50 years have only been possible due to the great help of innumerable individuals and institutions, who were acknowledged at the end of the symposium. While the future of the Commission is still uncertain beyond the year 2015, it is hoped that this symposium has underlined the urgent need for further glaciological and climatological monitoring and research.

Link to further information: www.glaziologie.de/Symposium2013

Ludwig Braun

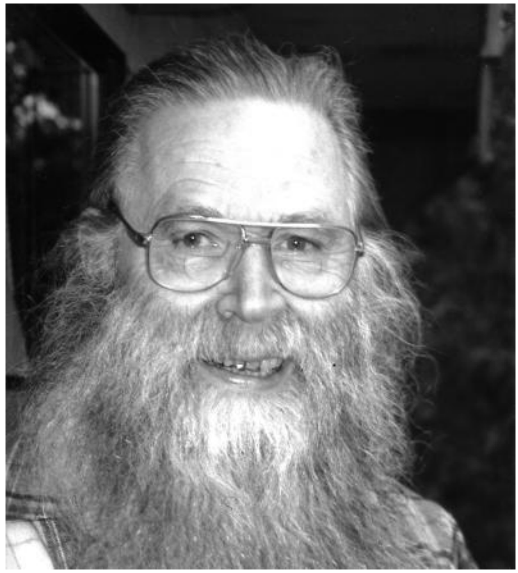
A mug with panoramas from Kreuzspitze in 1869 (painting) and in 2005 (photograph) was given to all participants

News

Obituary: Austin Post, 1922–2012

Variegated Glacier is a remote place. Emerging from a tight valley descending from the summit of Mount Jette, where the borders of Alaska, British Columbia and the Yukon Territory join, the glacier snakes down to the waters of Russell Fjord, its surface squamous with crevasses and debris, ending in a contorted nest of moraines. Among the earliest visitors to the glacier, geologist Ralph Tarr in 1905 named the Variegated Glacier for those moraines, whose various colors distinguished their provenance and suggested some profound complexity in the glacier's history. Subsequent observations were rare; other than the passage of the Canada–Alaska Boundary Survey during the earliest years of the 20th century, few visitors came into Russell Fjord with scientific objectives in mind. The glacier was occasionally captured in the background of photographs made of the larger and better-known Hubbard Glacier, but its identity and significance were mostly obscure, and its erratic behavior, recognized by Tarr and Martin but not yet codified as 'surging', was mysterious.

By the 1970s, Variegated Glacier had achieved its own modest fame as the epitome of the surging glacier, by virtue of a pair of aerial photographs taken by Austin Post in 1964 and 1965, showing the glacier in its pre-surge and post-surge states. Anyone seeing this iconic pair of images would immediately know the essential feature and drama of a glacier surge: the abrupt transformation of a glacier landscape on a grand scale. Until the early 1960s what little was known of the episodic, isolated occurrence of abrupt and rapid motion was ascribed to some triggering mechanism by earthquakes, as first detailed by Tarr and Martin in their 1914 discussion of the Variegated Glacier's 1904/05 surge. Austin Post took on the cause of glacier surging as one of his early glaciological goals, writing up his observations of several Alaska Range glacier surges in 1960; in 1965, he published the results of an epic program of aerial photography covering thousands of glaciers throughout Alaska and the Yukon. This exhaustive survey pointed to an internal dynamic instability as the cause of surging, rather than the action of earthquakes. Post himself evidently had been sure of the result from the outset, however, having published the internal dynamics explanation 6 years earlier as a hypothesis, one that he clearly subscribed to already.



Austin Post, 1990

That early leap to the true explanation was characteristic of Austin Post's working life. Analysis, documentation, validation – all of these were steps that Post frequently left to others, having satisfied himself that he understood and had articulated the solution to the problem in question. Along with the publications that he eschewed, however, often went recognition and even credit for ideas and explanations, leaving Austin's legacy somewhat obscure, preserved and defended by colleagues who knew and worked with him, but widely underappreciated in the larger glaciological world. Austin Post is known today mostly for his monumental efforts in aerial photography and the catalog of images, both beautiful and accurate, that came from it. His insights into glacier processes and glacier–climate interactions are less well known. Post's focus on discovery over dissemination was combined, perhaps, with a handicap produced by his own particular genius: his understanding of glaciers was so intrinsic to his nature, and so unfettered by conventional training and techniques of discovery, that detailed exposition and analysis may have seemed, if not difficult, at least superfluous. In Austin's view, if the mechanisms of glacier dynamics were so apparent, just how much explanation would be needed? His work and his life are both somewhat mysterious in this way: where did Austin's seemingly innate understanding of glaciers come from, and, more prosaically, what were the origins of his extraordinary range of technical skills and talents? No part of Austin Post comes from a predictable or easily knowable place.

The Post family – Austin, his parents, Asa and Beatrice, and his sister, Phyllis – lived in the town of Chelan, Washington, on the eastern slope of the Cascade Mountains, where Austin was born in 1922 and where his father owned and operated an orchard. By Austin's own account, his greatest childhood influences were the mountains surrounding Lake Chelan; a future as a fruit grower held little promise in those depression years and, despite a strong intellectual environment at home – both his parents were college graduates – Austin had little regard for school or his teachers. Dropping out of school at age 15, he worked for several years at odd jobs and explored the local peaks (including Mount Asa, first climbed by his father in 1908), eventually going to work on a US Forest Service trail crew. There he discovered the Forest Service's network of fire lookouts – perfect places of solitude and contemplation, ideally matched to Austin's introspective and observant nature – and by age 18 he was installed at the Pyramid Mountain Lookout near Lake Chelan. Within a year, however, the entry of the USA into the Second World War intervened, and Austin joined the Navy, serving a 4-year term in the Pacific as ship's carpenter.

Returning home in 1945 and finding no positions available in the Forest Service's fire lookout program, Austin combined two passions, boats and mountains, and signed on with the US Coast and Geodetic Survey Ship *Derickson* for a cruise to Alaska and Prince William Sound. There he had his first opportunities to explore large glaciers and their environment, watching closely as surveyors on board the *Derickson* mapped near-shore bathymetry, and making a few on-shore forays into the mountains.

Returning south, Austin began to make a career for himself as a carpenter and contractor in Seattle, working first with a master builder and later independently, building houses and experimenting with novel prefabrication methods. The mountains continued to exert a powerful attraction, however, and by 1953 Austin had his first opportunity to go into the mountains specifically for the business of science. Larry Nielsen, a chemist from Massachusetts and Austin's occasional climbing partner during the post-war years, had a scientific interest in glacier mechanics, spun off from his day-job research in the constitutive properties of polymers. Nielsen was an early participant in the Juneau Ice Field Research Project, and the 1953 field leader of a team whose tasks included establishing a triangulation network for surveys on the ice field. Austin was a capable surveyor, one of the skills he learned while working for the Forest Service, and Nielsen hired him to supervise the 1953 triangulation program. While not his first encounter with glaciers for reasons other than recreation, the summer on the Juneau Ice Field was transformative in two ways. In addition to giving Austin an opportunity to devote an extended period of time to the quantitative contemplation of glaciers in the company of others with matching interests, he also met meteorologist Dick Hubley, then a student in meteorology under Professor Phil Church at the University of Washington, and among the first American geoscientists to make an indepth investigation of energy transfer at glacier surfaces. Austin and Hubley formed a fast friendship, and Austin credited Hubley with saving his life on the Juneau Ice Field, when Austin developed severe

Post working on Columbia Glacier in 1957 pneumonia and Hubley made a dash to Juneau and back, bringing penicillin to treat him.

Hubley and Church both went on to play significant roles in the organization and planning of glaciological research for the International Geophysical Year (IGY), and Austin's connection with Hubley brought him into the small but growing group of geoscientists (glaciologists *per se* barely existed in the USA at this time, a situation soon changed by the outcome of the IGY) who were defining the scientific objectives to be pursued in polar and mountain regions during the IGY. William O. Field of the American Geographical Society of New York chaired the IGY Technical Panel on Glaciology, providing overall scientific guidance, recommendations on research objectives and study sites in the northern hemisphere. In addition to Church and Hubley, Bob Sharp from Cal Tech and Mark Meier, newly installed at the USA Geological Survey in Tacoma, Washington, served on the panel. These five members represented USA glaciological interests in the northern hemisphere, combining Field's geographical interests and expertise in cataloging and characterizing glacier extents through reconnaissance surveys, Church and Hubley's focus on meteorological and climatological processes, and Sharp and Meier's interests in glacier mechanics and dynamics. This scope of activities matched Austin's native curiosity and desire to photograph glaciers. When the specific decisions were made on what projects to pursue and where to pursue them, one task selected (Project 4.11 in IGY parlance) was a series of nine high-resolution topographic glacier maps, intended to form a baseline for future observations. Initial glacier selections were made by Bill Field, and the operation was delegated to Austin, supervising the surveys, and James Case, a graduate student at Ohio State University, to perform the photogrammetry. The field mapping was conducted in 1957 and 1958, but Austin's participation was cut short by an emergency: near the end of the 1957 field season, Dick Hubley, working on McCall Glacier in the Brooks Range, took his own life. Hubley's death created voids in the nascent glaciology community, and Austin stepped in to fill one of these, temporarily shifting his work from glacier mapping to energy balance and meteorology studies at McCall for the 1958 season. Hubley had finished his PhD at the University of Washington less than a year before, supervised by Phil Church and Frank Badgley. He had already created the Blue Glacier mass balance program and distinguished himself as arguably the foremost US expert on glacier micrometorology and mass balance processes.

The glaciological activities conducted in North America during the 1957/58 International Geophysical Year presented Austin with a great variety of possibilities. Having been brought to the attention of the glaciological leaders of the day, his interests and skills were an element in the ambitious long-term planning that took place in the years following the IGY. Glacier mapping and photography were long-standing interests of Bill Field, and Phil Church at UW had an interest establishing large-scale glacier observation programs. On a trip to Seattle, Austin, now doing work for Ed LaChapelle at Blue Glacier, met Phil Church and brought up a proposal he had conceived while tending Hubley's instruments at McCall Glacier. If one wanted to extend the 'Nine Glacier Maps' idea to a larger scale – a vastly larger scale – something more efficient than painstaking ground-based surveys would have to be employed. Austin's proposal involved photographing glaciers across the entire Alaska/Yukon region and creating photogrammetric base maps, or at least the raw materials to produce them. With input from Church, and his imprimatur, the proposal went to NSF and was eventually funded. Starting in 1960, after a long delay in a decision about funding followed by a very short advance notice of the award, Austin was off to Alaska with a military surplus K 24 aerial camera to meet pilot Don Sheldon. The project lasted for 4 years, with Austin shuttling back and forth over Alaska, piloted first by Sheldon and later by Port-Angeles-based Bill Fairchild, accompanied by magically cooperative weather and consistently functioning equipment.

Various lines of inquiry grew out of Austin's 1960–64 aerial photo project, questions that had occupied Earth scientists since the earliest glacier investigations in Alaska and were also well suited to Austin's genius for remembering landscapes and identifying changes. The episodic nature of glacier surging was known in very general terms to Earth scientists, but had been elaborated only to the extent that Tarr and Martin had presented in their 1914 Earthquake Advance theory. The 1960–64 photographic catalog, comprising some 4000 images, offered the best opportunity imaginable to test Tarr and Martin's Earthquake Advance theory since the interval serendipitously included, in its last year, the Alaskan Good Friday earthquake of 27 March 1964, located beneath the Chugach Mountains in the northwest corner of Prince William Sound and registering a Richter magnitude of 9.2. Photographs were repeated of glaciers and ample evidence of rockfall and avalanching was found, but no correlated evidence of rapid motion. Austin wrote up the results in a 1965 *Science* paper, laying to rest forever the Earthquake Advance theory, and opening the door to investigations of a glacier dynamics mechanism for surging, most likely involving (also Austin's suggestion) some role for internal hydrology as a modulator of rapid sliding.

Similarly, the majority of Alaska's tidewater glaciers, first seen at their fully extended positions in the late-18th-century reports of La Pérouse, Malaspina and Vancouver, were at various stages of rapid retreat by the late 19th and early 20th century, but no coherent explanation of their behavior had been proposed. Flying over them and taking note of their appearance, Austin started formulating a framework to think about their patterns of advance and retreat, observing, among other things, that those glaciers that showed extensive crevassing accompanied by fast motion, evidence of active calving and terminus retreat tended to terminate in relatively deep water, while glaciers with advancing termini, often bulldozing the forest ahead of them, rested in shallow water. The advantages of being able to see all 60 of Alaska's tidewater glaciers in quick succession and at many different stages in their advance/retreat cycle gave Austin a perspective no other Earth scientist had enjoyed before and, combined with his strongly visual way of thinking and capacity to compare and contrast the sight of a glacier before him with the memory of another glacier, provided insights that allowed him not only to answer fundamental outstanding questions about tidewater glacier behavior but to go beyond that to answer other important questions that no one else had yet thought to ask.

The funding for the initial 4-year program of aerial photography had expired, and some way had to be found to continue it if these new tasks were to be taken on. Phil Church and Austin were keen to continue photographing glaciers and pursuing the glacier–earthquake connection, but a request to NSF for an extension of their funding was declined. Church also found, to his dismay, that another research group had been awarded a similar grant by NSF, superseding and to a substantial degree duplicating their own work. On making inquiries, Church found that his own project hadn't been given a priority for continuation on the grounds that the original 1960 proposal hadn't made any mention of the earthquake.

A change in the funding structure for Austin's work needed to be established in any case: the photo missions had evolved into an ongoing observational program, outside the scope of NSF's central mandate, and needed a source of funding from some entity set up for long-term support. At this point, Mark Meier, the project chief of the USGS Project Office: Glaciology in Tacoma, Washington, stepped in and provided both the short-term solution to Austin's support problem and, as it turned out, the long-term solution as well. Meier also had a strong interest in glacier surging, the effects of the Good Friday earthquake and the nature of tidewater glaciers, and the USGS could justify the expense of a short but comprehensive mission to Alaska. Preparing once again at exceptionally short notice, Austin packed up his cameras and, taking off from a makeshift airstrip at his farm near Sequim, Washington, with Bill Fairchild piloting, made a 4-day circuit that covered the British Columbia/Alaska Coast Ranges, the Fairweather and St Elias mountains, the Chugach Range, Kenai Peninsula, Aleutians, Chigmit Mountains and Alaska Range – again, all in perfect weather. Austin's various abilities, the success of 5 years of aerial photo missions and the tantalizing potential of the information they contained all converged with the resources and mission of Meier's USGS Project Office, with the result that Meier gave Austin a job. Initially hired at technician level, he was elevated not long after to the level of a USGS professional scientist, a job that lasted for the rest of his working life. Building entirely on quick practical intelligence, self-taught skills and exceptional intuitive ability, Austin had found the freedom and opportunity to pursue the study and contemplation of glaciers that had fascinated him since his childhood among the mountains of the eastern Cascades.

For the balance of his career, Austin continued to work almost exclusively among the glaciers of western North America, from the Washington and Oregon Cascades to the Brooks Range in Alaska. Columbia Glacier, the location with which he is most closely associated, became the focus of his working life for more than two decades, and also enabled him to bring his love of boats and the ocean back into his work. As the builder, captain and most frequent occupant of the *Growler*, a refitted and reinforced 12 m navy surplus utility boat, Austin made Columbia and Heather Bays, immediately adjacent to Columbia Glacier's calving terminus, his home for many summers. The *Growler* served for many years, running bathymetric surveys, shuttling research staff to and from Columbia Bay, servicing a small survey hut near the glacier's terminus and offering warmth and shelter from the persistent rain of Prince William Sound. Aboard the *Growler*, Austin acted as both host and guiding spirit for Mark Meier's USGS Columbia Glacier team and scores of visiting scientists.

In the field, Austin was curious, independent and indefatigable. Joining Charlie Raymond and Will Harrison's research group working at Variegated Glacier in the 1970s, Austin disappeared one morning to make a reconnaissance of the lower glacier and its moraines, a region some 15 km in length, exceptionally rubbly underfoot, surrounded by oversteepened and unstable slopes, choked in alders and plagued by mosquitos in the

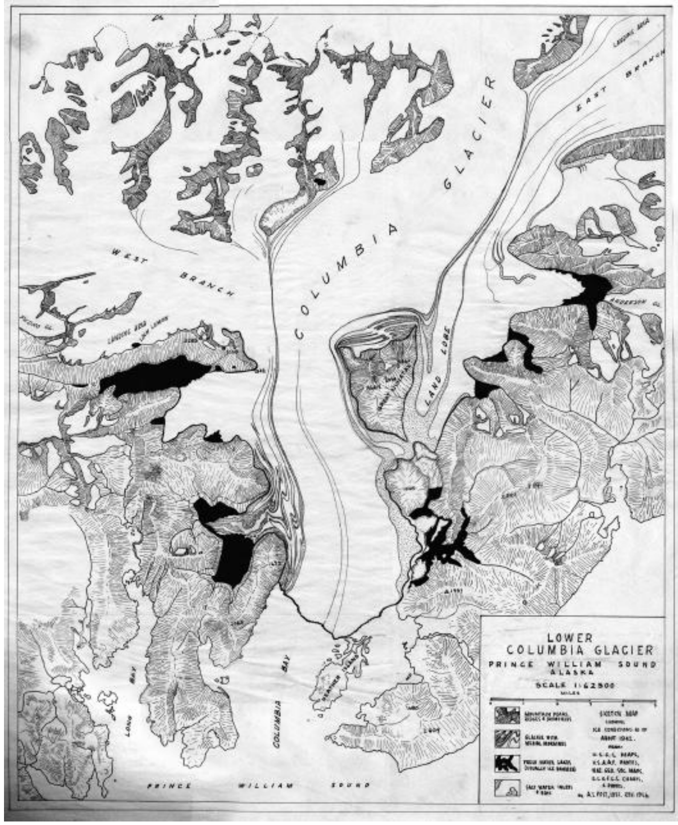
Austin with one of his sons and Will Harrison at Columbia Glacier, 1974

moraines adjacent to the ice. Late in the day Austin reappeared, a speck advancing slowly from far downglacier, bearing a map he had made, drawn on cardboard, the inside of a discarded box of Grape-Nuts cereal he had scavenged from the trash. The map showed the stratigraphic sequence of the nested moraines, revealing the order and origin of their emplacement – an effort suitable for a Master's degree in glacial geology, executed as a matter of curiosity in a day. (I first heard this story as a young graduate student. The fact that I initially understood it to mean that Austin had somehow drawn the map *inside* the box without disassembling it testifies to his reputation both for seemingly magical abilities and eccentricity.)

Many of Austin Post's accomplishments after joining the US Geological Survey are documented in the scientific literature covering tidewater glaciers, glacier surges and mass-balance observations on Alaskan glaciers. Austin continued to be far more concerned with continued exploration and discovery than with editorial negotiations, however, and many subsequent papers based on his foundational work were authored by others. He did put his name on some landmark papers: the review paper 'Fast Tidewater Glaciers', written by Mark Meier and Austin and published in 1987, remains the paper most often cited as defining the basic concepts of tidewater instability and retreat. His early papers on surging were definitive, codifying the term 'glacier surge', cataloging the geographic distribution of surging glaciers and making initial forays into the investigation of causes. Nevertheless, his contributions to theory are less well known than they deserve, possibly in part because his discoveries were regarded by some as too idiosyncratic, too dependent on a unique level of intuition. In a paper rejected by *Science* in 1968, he anticipated the role of hydrology and effective pressure in glacier surges, a result confirmed 20 years later by the long and detailed efforts of the field investigations at Variegated Glacier, conducted by Charlie Raymond, Will Harrison and Barclay Kamb. Other ideas, overflowing with potential, come up in conversations, letters and later emails with colleagues to whom he generously offered insights and inspiration for projects and discoveries too numerous for one person to keep track of.

His photography, for which he is justly revered, is among the most detailed visual environmental records ever assembled for scientific purposes; his book *Glacier Ice*, co-authored with Ed LaChapelle and first published in 1971, is a testimonial to the aesthetic quality of his photography as well as his close integration of visual information and beauty with quantitative observation and the construction of physical theory. The prime catalog of his life's photographic work – the large-format aerial photographic record begun in 1960 and continued in various phases for the next 25 years – is stored today at the University of Alaska at Fairbanks, with digitized versions now being prepared by Matt Nolan at the University of Alaska at Fairbanks, and online browsing catalogs are held at several other locations. In addition to these, however, Austin kept a large collection of his own glacier photography after his retirement, mostly in 6 × 6 and 6 × 9 cm medium format, every frame dated and cataloged. In the later years of his life, he started sending out boxes of film and other papers to various friends and colleagues, entrusting to them certain portions of his collection that he judged they would be most interested in and likely to both use and preserve. These boxes were invariably small treasures, containing not only valuable observations of glaciers but occasional records of day-to-day life and scenes photographed simply for pleasure. In one such photograph from 1974, Will Harrison, Austin and one of Austin's sons are at Columbia Glacier, dressed somewhat incongruously in the mode of the day and at work installing a survey target and instrument in a location on the ice now many kilometers distant from the glacier's receding terminus, and several hundred meters above the ocean surface that replaced it.

Handicapped in his later years by increasingly profound deafness, Austin tended to avoid face-to-face meetings, especially in groups, but was a faithful and enthusiastic correspondent, communicating a steady stream of ideas and commentary that, if anything, increased with age. Among his last meetings was a conversation at his Dupont, Washington, home in the autumn of 2010 with Shad O'Neel of the USGS Anchorage office, from which Columbia Glacier research is conducted today. Austin spoke little, responding mostly in gestures to Shad's prompting, but at one point firmly gripped Shad's arm, and implored him to keep the research program alive at Columbia Glacier. Another decade or two may be required before Columbia finally comes to its fully retreated position at the head of tidewater, and Austin wanted to be sure that, if he could not witness it himself, someone would be there to witness the completion of the cycle he had conceived of some half-century earlier.



Map of Columbia Glacier, hand-drawn by Austin Post, 1951

Austin Post's contributions to our knowledge of glaciers are known by the world of glaciology, his accomplishments were used by generations of researchers, his photography treasured for its scientific and artistic value. His achievements were recognized with an honorary PhD, awarded in 2004 by the University of Alaska at Fairbanks. His life and work would have been remarkable even if he had come to his career by a more conventional path, but the fact that he accomplished what he did without formal education after the age of 15 is extraordinary. Literacy, creative intelligence and articulate expression are scarcely reserved solely for those who have been through the 'normal' course of education, but Austin's abilities went far beyond mere eloquence. His early Juneau Ice Fields documents and his 1960 *Journal of Geophysical Research* paper on the surges of the Muldrow, Black Rapids, and Susitna Glaciers are much more than the reports of a capable ship's carpenter with a bent toward glaciers; they are mature scientific documents, written by a seasoned researcher, sure of his subject and well aware of and comfortable with the idioms of geosciences.

Nor can the generally accepted story of Austin's first encounter with glaciology on the Juneau Ice Fields in 1953 be quite right either. Among the film and papers that were my portion of the treasures distributed by Austin during his last days is a map, beautifully hand-drawn by him, showing the entirety of Columbia Glacier, its medial moraines accurately rendered, and even potential aircraft landing areas indicated in certain regions. It is, again, the work of a researcher who knows what belongs on such a map and has evident plans to use it in the future. And, like Austin himself, the map contains not only knowledge and beauty, but mystery as well: at the bottom of the map, below Austin's name, is the date: 1951.

Tad Pfeffer

Seligman Crystal for Paul Duval

Paul Duval has been at the forefront of international research to understand the physics of ice flow for 40 years. Many would say that he is still the leading researcher in microscale ice physics. He has made outstanding contributions to our understanding of ice flow with regard to the effects of impurities, including water, the impact of crystal size variations, and the rate-controlling processes of the deformation of ice. He characterized ice creep and unveiled the micromechanisms underlying the process. In addition, he championed modern modelling of the depth evolution of crystallographic texture and of the attendant development of plasticly anisotropic viscoplastic flow within both the Greenland and the Antarctic ice covers. Computational glaciologists continue to incorporate these effects into refined interpretations of ice core data and GCM models, much to the benefit of future climate predictions.

Early in his career, Paul published three papers that stand out as fundamental building blocks in glaciology. 'Fluage et recrystallisation dynamique de la glace polycristalline' (Duval (1972) *C. R. Acad. Sci. (Paris)*, **275**, 337–339) made clear for the first time that dynamic recrystallization contributes significantly to the acceleration of creep following the secondary stage. 'Anelastic behavior of polycrystalline ice' (Duval (1978), *J. Glaciol.*, **21**(85), 621–628) showed that, when load is removed, anelastic or recoverable strain accounts for a significant fraction of primary creep, an observation he explained in terms of dislocation back-slip. 'Rate-controlling processes in the creep of polycrystalline ice' (Duval and others (1983) *J. Phys. Chem.*, **87**, 4066–4074) established not only that plastic strain of relatively warm material (–10˚C) compressed under intermediate-to-high deviatoric stress (0.1–10 MPa) results principally from basal slip, but also that the rate of deformation is governed by a non-basal process. Most importantly, this paper showed that creepstrengthening (i.e. the reduction by a factor of 100 or more of the deformation rate upon transition from primary to secondary creep) is caused by the development of long-range interactions among the stress field of dislocations. This result laid the foundation for the understanding of the a later discovery that dislocations in ice move cooperatively and intermittently rather than individually and continuously, in the form of 'avalanches' or microbursts (Weiss and Grasso (1997) *J. Phys. Chem. B*, **101**, 6113–6117).

As Paul continued to explore the nature of creep, including, for instance, the study of creep-induced grain growth in polar ice (Montagnat and Duval (2000) *Earth Planet. Sci. Lett.*, **183**, 179-186), he also initiated a novel study on the modelling of inelastic deformation within glaciers and polar ice sheets. He realized early on that in such work it is critical, particularly in relation to the dating of ice cores, to take into account the plastic anisotropy that develops through the evolution of crystallographic texture: otherwise, predictions of ice age can be in error by thousands of years. Therefore, he incorporated not only an understanding of the physics of deformation but also new developments in materials mechanics on viscoplastic self-consistency (Hutchinson (1976) *Proc. R. Soc. London Ser. A*, **348**, 101–127; Hutchinson (1977) *Metal. Trans. A*, **8**, 1465–1469). This approach led to several excellent papers. For instance, 'Modelling fabric development along the GRIP ice core, central Greenland' (Castelnau, Duval and others (1996) *Ann. Glaciol.*, **23**, 194–201), 'Viscoplastic modeling of texture development in polycrystalline ice with a self consistent approach' (Castelnau, Duval and others (1996) *J. Geophys. Res.*, **101**, 13851–13878) and 'Modelling viscoplastic behavior of anisotropic polycrystalline ice' (Castelnau and others (1997) *Acta Mater.*, **45**, 4823–4834) all showed very good agreement with observation, thereby establishing the power of the combined physics–mechanics approach. A later paper, 'Elastoviscoplastic micromechanical modelling of the transient creep of ice' (Castelnau and others (2008) *J. Geophys. Res.*, **113**, B11203), accounted (in terms of the rheology of single crystals) for the permanent creep rate of several highly anisotropic samples harvested from Greenland.

More recent developments in which Paul is playing an important role include the study of dislocation 'avalanches'. The observation (Weiss and Grasso (1997) *J. Phys. Chem. B*, **101**, 6113–6117) that dislocations in ice move cooperatively and intermittently rather than individually and continuously is now attributed to the kind of long-range interactions among dislocations that Paul described in his 1983 paper (Duval and others (1983) *J. Phys. Chem.*, **87**, 4066–4074). Among others, notably Weiss and others (e.g. Weiss and others (2007) *Phys. Rev. B*, **76**, 224110), Paul and his collaborators (e.g. Montagnat and others (2006) *Phil. Mag.*, **86**, 4259; Chevy and others (2010) *Acta Mater.*, **58**, 1837–1849) have added to this evolving story by showing that the dislocation arrangement in deformed ice exhibits invariance of spatial scale and is therefore fractal in character. Another development, published in 'On the role of long range internal stresses on grain nucleation during discontinuous recrystallization' (Duval and others (2012) *Mater. Sci. Eng. A*, **546**, 207–211) is the idea that long-range dislocation interactions can eliminate the need for a critical nucleus, leading to the possibility of spontaneous nucleation not only in ice but also in other plasticly anisotropic materials such as zirconium. These developments in dislocation avalanches and barrier-free nucleation will inspire fundamental research on the plasticity of ice and other materials for years to come.

Paul's book, co-authored with Erland Shulson, *Creep and Fracture of Ice* (Cambridge University Press, 2009) is the first reasonably complete account of the physical mechanisms underlying the inelastic deformation of ice on scales small and large. Throughout the book, mechanisms that govern the behaviour of ice are related to mechanisms that control the behaviour of other materials, in support of the a view that Paul has held for many years (expressed directly in 'Creep and plasticity of glacier ice: a materials science perspective'; Duval and others (2010) *J. Glaciol.*, **56**(200), 1059–1068) that ice is a model material.

Paul is a humble person, with little to be humble about. He has served his profession well, with integrity and vigour and with clarity of thought. He has always been a keen teacher and communicator of his knowledge, keen to discuss research projects with others. He has inspired many students, several of whom are now recognized as excellent scientists in their own right. In November 2011, an international symposium (linked with the new ESF MicroDICE project) was held at Grenoble in his honour. That this symposium was instigated and organized by his current and past students demonstrates their admiration for his contribution to their own successes, and is a credit to him and to this work over the past 40 years.

Paul Duval has made a superb contribution to glaciology over the years, and the Awards Committee feel that the award of the Seligman Crystal is a fitting acknowledgement of his achievements.

INTERNATIONAL GLACIOLOGICAL SOCIETY

International Symposium on

Sea Ice in a Changing Environment

Hobart, Australia

10–14 March 2014

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The International Glaciological Society will hold an International Symposium on Sea Ice in a Changing Environment in 2014. The symposium will be held in Hobart, Australia from 10 to 14 March 2014. This will be the fourth IGS symposium dedicated to sea-ice research.

THEME

Sea ice plays a crucially important and dynamic role in global climate and high-latitude ecosystems. It forms a highly sensitive indicator and modulator of climate change and variability. Sea ice is currently one of the fastest responders to changing climate conditions across the globe – with both hemispheres responding differently overall but with regional similarities. This symposium presents a timely opportunity to showcase recent advances in our knowledge and technological capabilities, and to encourage holistic discussion of the most recent changes, long-term trends and variability in the sea-ice environment. Therefore, the symposium specifically includes topics pertinent to advancing our knowledge of sea ice from recent observations, advances in instrumentation and data processing, and progress in sea-ice and coupled modelling. To improve our understanding of the processes contributing to sea-ice change, including interactions with and response to other climatic components, and to fathom how sea-ice change may impact on ecosystem dynamics, biogeochemical systems, and polar operations, the symposium aims to provide a general discussion of changes in these components of the global cryosphere by providing a sounding board on the topics of cross-disciplinary data acquisition and exchange, technical improvements of observational and analytical tools, and integrated project planning.

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Tasmanian Government

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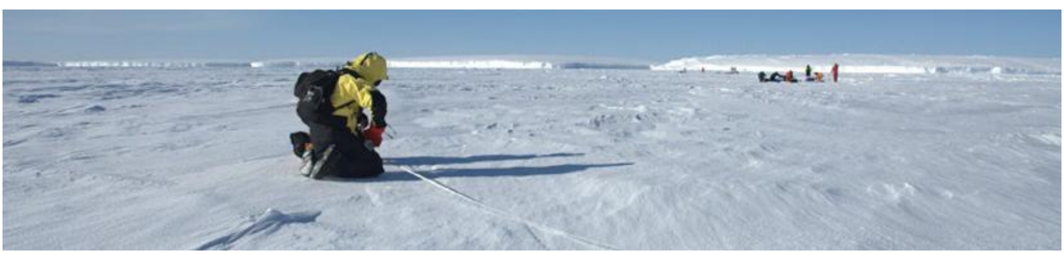
TOPICS

Meeting participants are encouraged to present on a wide variety of relevant topics, including

1. **Pole to pole: Large-scale change and variability in sea ice and climate**, including:
   regional to hemispheric response, teleconnections, attribution of change (including large-scale atmospheric and oceanic circulation changes and feedback mechanisms), and possible extreme events
2. **Seymour Laxon and Katharine Giles celebration session: Advances in sea-ice analysis using remotely sensed data**, including:
   hemispheric and global assessment, sea-ice thickness and volume, algorithm development and validation, accuracy of retrieved parameters, multisensor synergies, new technologies
3. **Advances in instrumentation and observation methods**, including:
   non-destructive observations, autonomous observatories (including underwater and aerial platforms), new analytical methods
4. **The challenge of melding sea-ice modelling with observations**, including:
   sea-ice and coupled model validation, advances in numerical parameterizations, current gaps, translating observations into models, IPCC-AR5 ensemble synthesis
5. **A new regime for sea-ice growth and decay?**, including:
   New observations of sea-ice growth and decay processes and of the characteristics of the sea-ice matrix, including the contribution of snow to sea-ice formation and decay (e.g. snow–ice and melt-pond formation), microphysical properties
6. **Snow on sea ice**, including:
   snow thickness, density, characteristics and processes, gas exchange, surface radiation budget and remote sensing considerations





7. **Interactions between sea-ice drift & deformation and sea-ice morphology**, including:
   ice kinematics, dynamics and mechanics, linkage to floe-size distribution and ice concentration, and dynamic effects on the sea-ice matrix
8. **Ocean–ice–atmosphere interactions**, including:
   boundary-layer processes, waves, tides, drag coefficients, synoptic scale forcing
9. **The marginal ice zone**, including:
   processes at the outer ice–ocean boundary, numerical and experimental advances in wave–ice interaction, wave attenuation, and floe-size modification
10. **Sea-ice interaction with ice sheets, ice shelves and icebergs**, including:
    fast ice, polynyas, basal melt and refreeze, water-mass modification, freshwater balance, oceanic heat content, and possible linkage to ice-shelf stability
11. **The role of sea ice in ecosystems dynamics**, including:
    sea-ice biota, primary productivity, microorganisms, microbial food webs, trophic levels
12. **Sea-ice biogeochemical properties and processes in a world of change**, including:
    gas fluxes, nutrients, trace elements, carbon and oxygen cycling, brine composition and nutrients
13. **Palaeo and pre-satellite sea ice distribution**, including:
    historical records and observations, reconstructions from ice core records and deep-sea sediments.

PROGRAMME

The symposium will consist of plenaries and oral sessions, with presentations in the 15′ (presentation) + 5′ (for questions and discussion) format as well as lightning presentations (3′ + 1′ format)/posters, with a large amount of free time to allow participants to exchange scientific information in an informal setting. Wednesday afternoon will be reserved for a symposium activity or excursion. The Governor of Tasmania will host a reception for delegates on Tuesday evening (RSVP required), and the symposium banquet will be held on Thursday evening.

Should you wish to hold a smaller break-out meeting, please contact petra.heil@utas.edu.au. Several side meetings have been confirmed, including:

- 8 March: International Antarctic Buoy Programme (IPAB) participants meeting
- 15 March: Antarctic Sea-ice Processes and Climate (ASPeCt) workshop
- 16 March: Climate and Cryosphere (CliC) Arctic sea-ice working group meeting (TBC)
- 17–19 March: SIPEX-2012 workshop.

A public science day involving interested participants is scheduled for the opening day of the symposium (9 March 2014).

REGISTRATION FEES

All fees are in Australian dollars, AUD

– Delegate (IGS member):	$650
– Delegate (not IGS member):	$780
– Student or retired (IGS member):	$325
– Student or retired (not IGS member):	$390
– Accompanying person (18 years or over):	$330
– Accompanying person (12–17 years):	$265
– Late registration surcharge (after 1 November 2013):	$100

The fees include the icebreaker, daily morning and afternoon tea, luncheons (Mon, Tues, Thurs, Fri), a mid-week excursion with packed lunch, reception at Tasmanian Government House (RSVP required) and the symposium banquet.

Please note that the deadline for full refund is 20 December 2013, while the deadline for partial (on a sliding scale) refund is 3 February 2014. After that, refund requests cannot be accepted. All refunds will be made less any bank charges. Payments made after 1 November 2013 must include the additional $100 late-registration fee.

ACCOMPANYING PERSONS: The accompanying persons' registration fee covers the icebreaker, the Government House reception (RSVP required), the mid-week excursion and the banquet, but not attendance at the presentation sessions. There is no charge for accompanying persons under 12 years.

VENUE

The symposium will be held at the Grand Chancellor Hotel in Hobart, the capital of Tasmania. Hobart has long played an important role in Australia's Southern Ocean and polar activities, originating in sealing and whaling pursuits as well as early expeditions. Today Hobart is Australia's hub for Antarctic and Southern Ocean activities, including science, education, logistics and tourism. These days, Hobart is home to many ocean, cryosphere and climate scientists.

Hobart lies close to 43°S and has a temperate marine climate. The city experiences a predominantly northwesterly air stream, and local weather is dominated by katabatic winds descending from the Wellington Range. The average rainfall for Hobart is 622 mm per year. Mount Wellington regularly receives snow, especially in winter and spring. While solid precipitation typically falls during winter, it can be encountered at any time of year. Consequently, one may experience 'four seasons in a day' while in Hobart. The symposium will be held in March in late summer, when the daily mean maximum and minimum temperatures are 20.7° and 10.3°C. For further information about Hobart see the Hobart Travel Centre, http://www.hobarttravelcentre.com.au/.

TRAVELLING TO HOBART

Several national airlines service Hobart with multiple flights per day. To enter Australia all international visitors need to present their visa. For more information please see your travel agent or the Australian Department of Immigration and Citizenship. Please note that Australia has strict quarantine rules, which apply to importing plants, animals and their products, including food.

ACCOMMODATION

Block bookings have been arranged at several hotels in Hobart for the duration of the symposium. To take advantage of these, please reserve rooms by 18 January 2014, noting that venues may fill up before then. We will release the rooms on 18 January, and cannot guarantee accommodation after that date. Most hotels are near the waterfront or in the city centre, within walking distance of the symposium venue. A list of available accommodation can be found on the conference website.

SYMPOSIUM ABSTRACTS AND THEMATIC PUBLICATION

Participants wishing to present a paper at the symposium are required to submit an abstract by 30 August 2013. Abstract submission is now open through the IGS web portal, http://www.igsoc.org/symposia/2014/hobart/. Each abstract will be assessed on its scientific merit and relevance to the symposium theme. Abstract acceptance will be communicated to the corresponding author on 4 October 2013. The programme and all accepted abstracts will be provided on a digital medium for all registered participants at the symposium.

The International Glaciological Society will offer a thematic volume of *Annals of Glaciology,* volume 56, issue 69, *Sea Ice in a Changing Environment* on topics consistent with the symposium topics, and participants are encouraged to submit manuscripts to this volume. When submitting abstracts to the symposium, you will be asked to indicate whether you intend to submit a paper for the *Annals* volume, so that reviewers may be sought in advance. Papers submitted for consideration in the *Annals* may not be submitted to another publication. Submission to this issue will not be contingent on presentation at the symposium, and material presented at the symposium is not necessarily accepted for inclusion in the *Annals*. The submission deadline for this *Annals of Glaciology* volume is 20 December 2013. Papers should be submitted through the IGS web portal and will be refereed according to the Society's exacting standards. We aim to complete reviews before the symposium, providing an opportunity for editors and authors to discuss the papers during the symposium.


Photo courtesy of Tony Lomas

SYMPOSIUM ORGANIZATION
Magnús Már Magnússon (International Glaciological Society)

SCIENTIFIC STEERING AND EDITORIAL COMMITTEE
Petra Heil (Chief Editor), Gerhard Dieckmann, Hiroyuki Enomoto, Sebastian Gerland, Ken Golden, Stefan Kern, Pat Langhorne, Robert Massom, James Renwick, Sharon Stammerjohn, Julienne Stroeve, Petteri Uotila

LOCAL ORGANIZING COMMITTEE
Petra Heil (Co-chair), Robert Massom (Co-chair), Ian Allison, Jo Jacka, Jan Lieser, Klaus Meiners, Jessica Melbourne-Thomas, Tony Press, Phil Reid and Guy Williams

FURTHER INFORMATION
Information will be updated on the conference website, http://seaice.acecrc.org.au/igs2014, as it becomes available

Please register online at www.igsoc.org/symposia/2014/hobart/registration
Registration will open in August 2013. In case of difficulty with the online registration, please contact the IGS office.

IMPORTANT DATES

International Symposium on Sea Ice in a Changing Environment

Abstract submission deadline:	30 August 2013
Notification of acceptance:	4 October 2013
Pre-registration deadline:	1 November 2013
Student/postdoc travel support application deadline:	18 October 2013
Deadline for full refund:	20 December 2013
Deadline for partial refund:	3 February 2014
Icebreaker and registration desk opens:	9 March 2014
Symposium:	10–14 March 2014

Annals of Glaciology volume 56, issue 69

Paper submission deadline:	20 December 2013
Final revised papers deadline:	14 April 2014

INTERNATIONAL GLACIOLOGICAL SOCIETY

International Symposium on

Contribution of Glaciers and Ice Sheets to Sea-Level Change

(observations, modelling and prediction)

Chamonix–Mont-Blanc, France
26–30 May 2014

Co-sponsored by:

Laboratoire de Glaciologie et Géophysique de l'Environnement
Labex OSUG@2020 (Investissements d'avenir – ANR10 LABX56)
ANR project SUMER
ESF Networking Programme MicroDIce
Centre National de la Recherche Scientifique (CNRS INSU & INSIS)
Université Joseph Fourier – Grenoble I
Ecole Nationale de Ski et d'Alpinisme (ENSA)

SECOND CIRCULAR
July 2013
http://www.igsoc.org/symposia/2014/chamonix
http://www-lgge.obs.ujf-grenoble.fr/igs2014/

The International Glaciological Society will hold an International Symposium on 'Contribution of Glaciers and Ice Sheets to Sea-Level Change (observations, modelling and prediction)' in 2014. The symposium will be held in Chamonix–Mont-Blanc, France, from 26–30 May 2014.

THEME

Glaciers, ice-caps and ice-sheets experiencing a warming climate are expected to present an increasing contribution to sea-level rise. Linkages with the other components of the climate system, especially the atmosphere and ocean, are fundamental aspects of the complexity of ice-mass response to changing climate.

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SUMER

ECOLE NATIONALE DE SKI ET D'ALPINISME

Micro-DICE
ESF Research Networking Programme
Micro-Dynamics of Ice

UNIVERSITE JOSEPH FOURIER
SCIENCES TECHNOLOGIE MEDECINE
GRENOBLE 1

LabEx OSUG@2020

L G G E
Laboratoire de Glaciologie et Géophysique de l'Environnement

Observatoire des Sciences de l'Univers de Grenoble

Observations at the interfaces between atmosphere/cryosphere and ocean/cryosphere have considerably increased our understanding of the complex coupling prevailing between the systems, though strong uncertainties remain. At the same time, ice-flow models have greatly improved over the last few years, but essential processes such as basal hydrology or calving remain strongly parameterized. Strong initiatives to couple ice-flow models to ocean and/or atmosphere models have emerged, but the process of integrating remains challenging. This symposium seeks to address these problems by bringing together experts in cryosphere, climate and oceanography, from both the observation and modelling sides.

TOPICS

Meeting participants are encouraged to present on a wide variety of topics. All these topics can be addressed using observations, forward or inverse modelling, theoretical analysis or the coupling of data and modelling through the use of data assimilation methods. The first six topics are more related to a specific interface and focus on local processes, whereas topics 7 and 8 seek to address the large-scale response of ice mass.

1. **Basal processes**: effect of basal water, link between runoff and surface velocity, hydrological model, friction law linking basal hydrology and water pressure, drumlins and associated sub-glacial landforms
2. **Basal melting** below ice-shelves and at the front of marine terminated glaciers, distribution and amount of melt, accretion of marine ice, coupling of ice sheet and ocean models
3. **Grounding-line dynamics**: marine ice-sheet instability, observed rate of migration, positioning by various techniques, sensitivity of the rate of migration of grounding line to forcing regimes



4. **Calving processes**: calving rate parameterization, damage modelling, numerical implementation in ice-sheet models
5. **Surface mass balance**: snow accumulation and runoff, influence of refreezing in firn, coupling of regional climate and ice-sheet models
6. **Ice body and rheology**: anisotropy, temperature field within ice masses, borehole records, rheology of marine ice, modelling of englacial structure
7. **New generation of ice-sheet models**, their numerical design, impact of mechanics, their coupling with ocean and/or climate
8. **Estimation of the contribution of glaciers and ice-sheets to sea-level change**: initialization (spin-up), forecast estimates of future sea-level rise, ensemble methods, and associated error bars, paleo-reconstruction of past change.

ABSRACT AND PAPER PUBLICATION

Participants wishing to present a paper (either oral or poster) at the symposium will be required to submit an abstract by 31 January 2014. A programme and collection of submitted abstracts will be provided for all participants at the symposium. The Council of the International Glaciological Society has decided to publish a thematic issue of the *Annals of Glaciology* on topics consistent with the symposium themes. Submissions to this issue will not be contingent on presentation at the symposium, and material presented at the symposium is not necessarily affirmed as being suitable for consideration for this issue of the *Annals*. Participants are encouraged, however, to submit manuscripts for this *Annals* volume. The deadline for receiving *Annals* papers is 31 March 2014.

REGISTRATION FEES
All fees are in Euros, €

– Participant (IGS member):	400€
– Participant (not IGS member):	540€
– Student or retired (IGS member):	200€
– Student or retired (not IGS member):	270€
– Accompanying person (18+):	160€
– Accompanying person (12–17):	100€
– Accompanying person (<12):	Free
– Late registration surcharge (after 3 March 2014):	80€

The fees include the icebreaker, the symposium banquet, lunch (Mon–Fri) daily morning/afternoon coffee and the mid-week excursion. Because of the limited size of the ENSA conference room (195 seats) late registrations might not be accepted.

REGISTRATION BY MAIL: Though we strongly prefer registration through the website, if you cannot do so, contact the IGS office directly. If payment by credit card is not possible, contact the IGS office to arrange for a bank transfer. Payments made after 3 March 2014 must include the additional 80€ late-registration fee.

ACCOMPANYING PERSONS: The accompanying person's registration fee includes the icebreaker, the mid-week excursion and the symposium banquet. It does not include attendance at the presentation sessions.

STUDENT/POSTDOC SUPPORT: Funding is available to partially support student and postdoc attendance at this symposium. Application details will be posted on the symposium homepage in October 2014 at the latest.


VENUE

The meeting will be held at the Ecole Nationale de Ski et d'Alpinisme (ENSA) in Chamonix–Mont-Blanc, France. Chamonix–Mont-Blanc is located close to the Italian and Swiss borders, in the French Alps. Chamonix–Mont-Blanc is situated at an altitude of 1100 m and is surrounded by high mountains, among them Mont-Blanc (4810 m). Chamonix–Mont-Blanc being one of the most visited places in France, the region offers plenty of activities. The nearest airport is Geneva (88km, bus and minibus connections).

ACCOMMODATION

ENSA offers a limited number of student-type rooms for two persons (separate washroom and toilet for each room). The allocation of the rooms will be on a first-come-first-served basis. Indicate during the reservation process with whom you want to share the room. Single rooms are also available on payment of a surcharge. When registering for the symposium, you may choose one of the following options:

- Lodging at ENSA in single room: 285€
- Lodging at ENSA in shared room (2 persons): 210€ per person
- Additional night (+ breakfast) – Friday 30 May: 30€ (2 persons), 45€ (single)
- Dinners at ENSA: 60€.

The option 'Lodging at ENSA' includes five nights (+breakfast) from Sunday to Friday in a student-type room and four dinners (Sunday to Wednesday). The option 'Dinners at ENSA' includes four dinners in the ENSA cafeteria (Sunday to Wednesday) and is offered to people who are staying in a hotel but would like to dine at ENSA. An additional night and an additional dinner can be booked for Friday 30 May, but only for people who have chosen the option 'Lodging at ENSA'. No booking at ENSA is possible before Sunday 25 May, or after Friday 30 May

In addition, there are many hotels within walking distance of ENSA. Information can be obtained by contacting the Chamonix–Mont-Blanc tourist office. More information will be posted on the symposium homepage.

MIDWEEK ACTIVITIES
A half-day midweek excursion will be organized on Wednesday afternoon. Depending on the weather, you will have the opportunity to take the cable car up to the Aiguille du Midi (3842 m) and take a guided tour led by LGGE researchers, or to take the Mont-Blanc train to access the Mer de Glace glacier and visit the ice cave and the glaciorium at Montenvers. A small group of us may have the privilege to reach the area below the Mer de Glace using the EDF gallery (to be confirmed). More information will become available on the symposium homepage.

RECEPTION
There will be an Icebreaker reception at ENSA on Sunday 25 May. You will be able to pick up your registration package after 4 pm. Come along to meet your fellow delegates, get orientated at the conference site and pick up your registration package.

BANQUET
The banquet will be held on Thursday evening. More information will become available on the symposium homepage.

SYMPOSIUM ORGANIZATION
Magnús Már Magnússon (International Glaciological Society)

SCIENTIFIC STEERING AND EDITORIAL COMMITTEE
Richard Hindmarsh (BAS, UK) and Frank Pattyn (ULB, Belgium), Co-Chief Editors; Gudfinna Adalgeirsdottir, Tamsin Edwards, Gwendolyn Leysinger Vieli, Martin Lüthi, Kerim Nisancioglu, Louise Sorensen, Shin Sugiyama, Lev Tarasov and Ralf Timmermann. Further Scientific Editors will be appointed as necessary.

LOCAL ORGANIZING COMMITTEE
Olivier Gagliardini (Chair), Gaël Durand, Fabien Gillet-Chaulet, Emmanuel Le Meur, Maurine Montagnat, Luc Moreau, Vincent Peyaud, Armelle Philip, Catherine Ritz, Christian Vincent and Jérôme Weiss

CONTACTS FOR FURTHER INFORMATION

Magnús Már Magnússon
International Glaciological Society
Scott Polar Research Institute
Lensfield Road, Cambridge, CB2 1ER, UK
Tel: +44 (0)1223 355 974 / Fax: +44 (0)1223 354 931
Email: igsoc@igsoc.org / Web: http://www.igsoc.org/symposia/2014/chamonix/

Olivier Gagliardini
Laboratoire de Glaciologie et Géophysique de l'Environnement
54, rue Molière
BP 96, 38402 Saint-Martin-d'Hères Cedex, France
Tel: +33 (0)4 76 82 42 76 / Fax: +33 (0)4 76 82 42 01
Email: olivier.gagliardini@ujf-grenoble.fr

FURTHER INFORMATION

Information will be updated on the conference website, http://www-lgge.obs.ujf-grenoble.fr/igs2014/index.html, as it becomes available

Please register on line at www.igsoc.org/symposia/2014/chamonix/registration
Registration will open in August 2013.

IMPORTANT DATES

International Symposium on Sea Ice in a Changing Environment

Abstract submission deadline:	31 January 2014, 23:59 GMT
Notification of acceptance:	14 February 2014
Pre-registration deadline:	3 March 2014
Deadline for full refund:	31 March 2014
Deadline for partial refund:	1 May 2014
Registration and Icebreaker:	25 May 2014
Symposium starts:	26 May 2014

Annals of Glaciology volume 56, issue 70

Paper submission deadline:	31 March 2014
Final revised papers deadline:	1 August 2014

Glaciological diary

** IGS sponsored * IGS co-sponsored

2013

2–5 April 2013
Snow grain size workshop – measurements and applications
Grenoble, France
Website: http://snowgrain2013.sciencesconf.org/

4–5 April 2013
Conference: Holocene Climate Change
London, UK
Contact Steve Whalley [steve.whalley@geolsoc.org.uk]

7–12 April 2013
European Geosciences Union General Assembly 2013
Vienna, Austria
Website: http://www.egu2013.eu/

13–19 April 2013
Arctic Science Summit Week
Krakow, Poland
Website: http://www.assw2013.us.edu.pl/registration

29 April–2 May 2013
American Meteorological Society: 12th Conference on Polar Meteorology and Oceanography
Seattle, Washington, USA
Website: http://www.ametsoc.org/MEET/fainst/201312polarocean.html

14–17 May 2013
AGU 2013 Meeting of the Americas
Cancun, Mexico
Website: http://moa.agu.org/2013/

30 May–2 June 2013
International Association of Geodesy International Symposium: Reconciling observations and models of elastic and viscoelastic deformation due to ice mass change
Ilulissat, Greenland
Website: http://www.dtu.dk/subsites/iag.aspx

3–7 June 2013
International Workshop: Understanding the response of Greenland's marine terminating glaciers to oceanic and atmospheric forcing
Near Boston, Massachusetts, USA
Website: http://www.usclivar.org/meetings/griso-workshop/

16–18 June 2013
International Conference on Geology and Geophysics
Beijing, China
Website: http://www.engii.org/workshop/icgg2013/

17–19 June 2013
27th international Forum for Research into Ice Shelf Processes (FRISP)
Gregynog Hall, Powys, Wales
Contact Adrian Jenkins [ajen@bas.ac.uk]

18–21 June 2014
4th European Conference on Permafrost – IPA Regional Conference (EUCOP4)
Évora, Portugal
Website: http://www.eucop4.org/

24–28 June 2013
Asia Oceania Geosciences Society (AOGS) 10th Annual Meeting
Brisbane, Australia
Website: http://mpi.ysn.ru/index.php/en/welcome.html

24 June–13 July 2013
Third Forum for Young Permafrost Scientists
Yakutsk, Russia
See forum website

8–12 July 2013
Joint IACS/IAMAS Conference: Air and ice – interaction processes
Davos, Switzerland
Contact: Charles Fierz [fierz@slf.ch]
Website: http://www.daca-13.org/index_EN

22–26 July 2013
Knowledge for the Future: IAHS/IAPSO/IASPEI Joint Meeting
Gothenburg, Sweden
Website: http://iahs-iapso-iaspei2013.com/

28 July–2 August 2013
****International Symposium on Changes in Glaciers and Ice Sheets: observations, modelling and environmental interactions**
Beijing, China
Contact: Secretary General, International Glaciological Society
Website: http://www.igsoc.org:8000/symposia/2013/beijing/

14–16 August 2013
NASA Snow Remote Sensing Workshop
Boulder, Colorado, USA
Contact: Matthew Sturm [matthew.sturm@gi.alaska.edu], Chris Derksen [Chris.Derksen@ec.gc.ca], Mark Serreze [serreze@nsidc.org], Jared Entin [jared.k.rnyin@nasa.gov]
Website: http://www.nasasnowremotesensing.gi.alaska/edu/

18–22 August 2013
Canadian Quaternary Association (CANQUA) biennial meeting
Edmonton, Alberta, Canada
Special session: Past and present ice sheet and glacier hydrology
Contact: Andrew Perkins [ajp7@sfu.ca], Tracy Brennand [tabrenna@sfu.ca]
Website: http://www.eas.ualberta.ca/canqua/

19–31 August 2013
Advanced Climate Dynamics Course 2013: The dynamics of the last deglaciation
Nyksund, Vesterålen Islands, Norway
Website: http://kurs.uib.no/acdc/index.html

22–24 August 2013
28th Himalayan Karakorum Tibet Workshop and 6th International Symposium on Tibetan Plateau Joint Conference
Tübingen, Germany
Website: http://www.tip.uni-tuebingen.de/index.php/en/hkt-istp-2013-tuebingen

25–30 August 2013
Goldschmidt Geochemistry Meeting
Florence, Italy
Website: http://www.goldschmidt.info/2013/

26–29 August 2013
International Workshop on Antarctic Ice Rises
Tromsø, Norway
Website: http://www.climate-cryosphere.org/index.php/meetings/ice-rises-2013/

26–29 August 2013
8th IAG International Conference on Geomorphology
Paris, France
Website: http://www.geomorphology-iag-paris2013.com

26–30 August 2013
****Workshop on Subglacial Hydrology**
Institute of Earth Sciences, Reykjavik, Iceland
Website: http://www.earthice.hi.is/conferences_and_workshops/

27–31 August 2013
8th IAG International Conference on Geomorphology
Paris, France
Website: http://www.geomorphology-iag-paris2013.com/

4–5 September 2013
****International Glaciology Society British Branch Meeting 2012**
Loughborough, UK
Contact: Richard Hodgkins [r.hodgkins@lboro.ac.uk]

8–12 September 2013
5th Polar and Alpine Microbiology Conference
Big Sky, Montana, USA
Website: http://polaralpinemicrobiology2013.montana.edu/

9–13 September 2013
****International Symposium on Radioglaciology: advances in radio frequency, microwave and digital technologies**
Lawrence, Kansas, USA
Contact: Secretary General, International Glaciological Society
Website: http://www.igsoc.org:8000/symposia/2013/kansas/

9–13 September 2013
***7th International Workshop on Ice Drilling Technology**
University of Wisconsin, Madison, WI, USA
Website: http://icedrill.org/7th-international-workshop-on-ice-drilling-technology/

10–21 September 2013
The annual Karthaus course on Ice Sheets and Glaciers in the Climate System
Karthaus (northern Italy)

16–18 September 2013
Mountainhazards 2013: Natural hazards, climate change and water in mountain areas
Bishkek, Kyrgyzstan
Website: http://www.mountainhazards2013.com/

18–20 September 2013
Third UK Arctic Science Conference
Scott Polar Research Institute, Cambridge, UK
Website: http://www.arctic.ac.uk/research/uk-arctic-science-conference-2013/snowphysics.fegi.ru/en/main.html

22–28 September 2013
International symposium: Physics, chemistry and mechanics of snow
Yuzhno-Sakhalinsk, Russia
Website: http://snowphysics.fegi.ru/en/main.html

23–24 September 2013
Transantarctic Mountains Science Meeting
Minneapolis, Minnesota, USA
Website: http://tamcamp.org/

23–28 September 2013
****International Symposium: Physics, chemistry and mechanics of snow**
Yuzhno-Sakhalinsk, Russia
Website: http://snowphysics.fegi.ru/en/main.html

29 September–2 October 2013
West Antarctic Ice Sheet (WAIS) Workshop
Sterling, Virginia, USA
Contact: waisworkshop@nsidc.org

29 September–3 October 2013
Earth Cryology: XXI century
Pushchino, Russia
Website: http://cryosol.ru/index/earth_cryology2013/0-45

3–4 October 2013
Elmer/Ice course for beginners
LGGE, Grenoble, France
Contact: Olivier Gagliardini [olivier.gagliardini@ujf-grenoble.fr]
Website: http://www.issw2013.com/

7–11 October 2013
ISSW International Snow Science Workshop 2013
Grenoble and Chamonix Mont-Blanc, France
Website: http://www.issw2013.com/

12–19 October 2013
DISCCRS VIII Interdisciplinary Climate Change Research Symposium
Colorado Springs, Colorado, USA
Website: http://disccrs.org/

18–19 October 2013
North West Glaciologists meeting
Vancouver, BC, Canada

27-30 October 2013
Geological Society of America
Denver, Colorado, USA
Session T30: Past records and future challenges of glacier and ice sheet response to climate change: honouring and building on the legacy of Mark Meier
Contact: Scott Lundstrom [sclundst@usgs.gov]
Website: http://community.geosociety.org/2013AnnualMeeting/Sessions

31 October–2 November 2013
****International Glaciological Society Nordic Branch Meeting 2013**
Lammi, Finland
Contact: Onni Järvinen[onni.jarvinen@helsinki.fi]
Website: http://www.physics.helsinki.fi/conf/IGSNB2013/IGSNB2013.html

7–8 November 2013
Antarctic Geologic Drilling Workshop
Houston, Texas, USA
Contact: Julia Wellner [jwellner@uh.edu]
Website: http://eas.uh.edu/agdw/

9–13 December 2013
AGU Fall Meeting
San Francisco, California, USA
Website: http://fallmeeting.agu.org/2013/

2014

3–5 February 2014
IASC Workshop on the Dynamics and Mass budget of Arctic Glaciers
Ottawa, Canada
Contact: Carleen Tihm-Reijmer [c.h.tijm-reijmer@uu.nl]
Website: http://www.iasc.info/nag/

10–14 March 2014
****International Symposium on Sea Ice**
Hobart, Australia
Contact: Secretary General, International Glaciological Society

17–20 March 2014
13th International Conference on the Physics and Chemistry of Ice (PCI-2014)
Hanover, New Hampshire, USA
Website: http://engineering.dartmouth.edu/pci-2014

26–30 May 2014
****International Symposium on Observations, Modelling and Prediction of the Cryospheric Contribution to Sea Level Change**
Chamonix, France
Contact: Secretary General, International Glaciological Society

18–21 June 2014
EUCOP4: 4th European Conference on Permafrost
Évora, Portugal
Website: http://www.eucop4.org/

17–22 August 2014
International Workshop on Ice Caves (IWIC)
Idaho Falls, Idaho, USA
Website: http://www.iwic-vi.org/

18–23 August 2014
****International Symposium on the Changing Arctic Cryosphere**
Edmonton, Alberta, Canada
Contact: Secretary General, International Glaciological Society

22 August–3 September 2014
XXXIII SCAR Biennial Meetings and Open Science Conference
Auckland, New Zealand
Contact: Katrina Hall [gateway-antarctica@canterbury.ac.nz]
Website: http://www.scar2014.com/

2015

June 2015
****International Symposium on the Hydrology of Glaciers and Ice Sheets**
Iceland
Contact: Secretary General, International Glaciological Society

August 2015
****International Symposium on Contemporary Ice-Sheet Dynamics: ocean interaction, meltwater and non-linear effects**
Cambridge, UK
Contact: Secretary General, International Glaciological Society

2016

20–24 June 2016
Eleventh International Conference on Permafrost (ICOP 2016)
Potsdam, Germany
Website: http://icop2016.org/

August/September 2016
****International Symposium on Polar Sea Ice, Polar Climate and Polar Change**
Boulder, Colorado, USA
Contact: Secretary General, International Glaciological Society

New members

Salvatore G. Candela
Earth Science, Alaska Pacific University
41-01 University Drive, Appt N30, Anchorage, AK 99508, USA
Tel +1 347-604-1382
E-mail scandela@alaskapacific.edu

Ms Jenny M. Chierici
Institute of Marine Research
Sykehusveien 23, Postboks 6404,
NO-9294 Tromsø, Norway
Tel +47 77609754
E-mail melissa.chierici@imr.no

Mr Richard C. Chiverrell
Environmental Sciences, University of Liverpool
Roxby Building, Geography and Planning, Liverpool, L69 7ZT, UK
Tel +44 (0)151 7942834
E-mail rchiv@liv.ac.uk

Mr Jeff Crompton
Department of Earth Sciences, Simon Fraser University
8888 University Drive, Burnaby, BC, V5A 1S6, Canada
Tel +1 778-938-3871
E-mail jcrompto@sfu.ca

Ms Bethan Davies
Institute of Geography and Earth Sciences, Aberystwyth University
Llandinam Building, Penglais Campus, Aberystwyth, Ceredigion, SY23 3DB, UK
Tel +44 (0)7967288274
E-mail bdd@aber.ac.uk

Dr Jan de Rydt
British Antarctic Survey
High Cross, Madingley Road, Cambridge, CB3 0ET, UK
E-mail janryd69@bas.ac.uk

Dr Ding Minghu
Climate system institute, Chinese Academy of Meteorological Sciences
Zhongguancun Nandajie 46, Haidian district, Beijing, 100081, P.R. China
Tel +86 10 58993791
E-mail dingminghu@cams.cma.gov.cn

Mr Paul Fisher
Science, Morristown-Beard School
42 Diller Way, Hampton, NJ 08827, USA
E-mail pfisher@mbs.net

Professor Masato Furuya
Department of Natural History Sciences, Hokkaido University, N10W8, Kitaku, Sapporo
Hokkaido 060-0810, Japan
Tel +81 117062759
E-mail furuya@mail.sci.hokudai.ac.jp

Gao Yang
Institute of Tibetan Plateau Research
Chinese Academy of Sciences, 18 Shuangqing Rd, PO Box 2871, Beijing 100085, P.R. China
Tel +860-15910782169
E-mail yanggao@itpcas.ac.cn

Dr Alex Gardner
Graduate School of Geography, Clark University
950 Main St, Worcester, MA 01610, USA
E-mail agardner@clarku.edu

Ms Alexandra Giese
Earth Sciences, Dartmouth College
HB6105 Fairchild Hall, Department of Earth Sciences, Hanover, NH 03755, USA
Tel +1 6178355848
E-mail alexandra.l.giese.gr@dartmouth.edu

Ms Saskia Gindraux
Physical Geography, University of Zurich
Altwiesenstrasse 185, CH-8051 Zurich, Switzerland
Tel +41 797918625
E-mail saskia.gindraux@gmail.com

Mr Brian Gould
Alpine Solutions Avalanche Services
PO Box 417, Squamish, BC, V8B 0A4, Canada
E-mail bgould@avalancheservices.ca

Ms Hayley L. Green
Hull University
Cottingham Rd, Hull, Yorkshire, HU6 7RX
Tel +44 (0)1482 346311
E-mail hayley.l.g@hotmail.co.uk

Mr Stelian Grigore
Universitatea Populara 'Emil Racovita' Piatra Neamt
Casa de Cultura, Universitatea Populara, B-dul Republicii nr. 15, Piatra Neamt, 610005 Judetul Neamt, Romania
Tel +40-0735170005
E-mail stelian.grigore@gmail.com

Ms Hrafnhildur Hannesdóttir
Institute of Earth Sciences, University of Iceland
Sturlugata 7, IS-101 Reykjavík, Iceland
E-mail hrafnha@hi.is

Mr Tom Hurst
Department of Geography, University of Sheffield
Winter Street, Sheffield, S10 2TN, UK
E-mail tom.hurst@sheffield.ac.uk

Ms Jerilynn Jackson
Geography, University of Oregon
1222 E 13th Ave, M40-253, Eugene, OR 97403, USA
Tel +1 541 232 8786
E-mail jerilynn@uoregon.edu

Mr Thomas Joy
University of York
Heslington, York, North Yorkshire, YO10 5DD
E-mail tpj501@york.ac.uk

Dr Thomas Kleiner
Alfred Wegener Institute for Polar and Marine Research
Am Alten Hafen 26, D-27568 Bremerhaven, Germany
E-mail thomas.kleiner@awi.de

Dr Benoit Legresy
LEGOS, CNRS
14 Avenue Edouard BELIN, F-31400 Toulouse, France
Tel (33)561332956
E-mail benoit.legresy@gmail.com

Mr Michael MacFerrin
University of Colorado Boulder
216 UCB, Boulder, CO 80309, USA
Tel +1 3035659920
E-mail michael.macferrin@colorado.edu

Mr Ilay Marchuk
Borovskoe shosse 29/76, 119633 Moscow, Russia
E-mail ilmarch93@gmail.com

Mr Joshua Maurer
4390 N 3175 E, Liberty, Weber, UT 84310, USA
Tel +1 801 448 9243
E-mail josh3996@gmail.com

Miss Natasha Milburn
Northumbrian Water
Boldon House, Wheatlands Way, Pity Me, Durham, DH1 5FA UK
Tel +44 (0)1388 745827
E-mail natashamilburn@hotmail.co.uk

Mr Andrew Roberts
Oceanography, Naval Postgraduate School
833 Dyer Rd, Bldg. 232, Room 339A, Monterey, CA 93943, USA
Tel +1 831-656-1836
E-mail afrobert@nps.edu

Mr Daniel John Robinson
Northumbria University
11 Queens Road, Wooler, Northumberland, NE71 6DR, UK
E-mail danrobinson2391@gmail.com

Dr Mario Rohrer
Meteodat
Riedtstrasse 8b, CH-8903 Birmensdorf, Switzerland
Tel +41447374214

Dr Morimasa Takata
Mechanical Engineering, Nagaoka University of Technology
Kamitomioka 1603-1, Nagaoka, Niigata, 940-2188, Japan
E-mail morimasa@mech.nagaokaut.ac.jp

Mr Renoj J. Thayyen
Western Himalayan Regional Centre, National Institute of Hydrology
Flood Control Complex, Satwari, Jammu, Kashmir, 180003, India
E-mail renojthayyen@gmail.com

Ms Laura Thomson
Department of Geography, University of Ottawa
Simard Hall, 60 University, Ottawa, Ontario, K1N5Z7, Canada
Tel +1 (613) 859-5679
E-mail lthom021@uottawa.ca

Mr Kenta Tone
FUKUDA Hydrological Center Co., Ltd.
9-3-7-203, Kita-ku, Kita22, Nishi, Sapporo, Hokkaido, 001-0022, Japan
Tel +81 090-2043-3224
E-mail tonekenta@gmail.com

Mr Jonathan Wheatland
School of Engineering & Material Sciences, Queen Mary, University of London
Mile End Road, London, E1 4NS
Tel +44 (0)1923840957
E-mail j.a.t.wheatland@qmul.ac.uk