

ICE



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OF THE INTERNATIONAL
GLACIOLOGICAL
SOCIETY***



Ice

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Contents

2 From the Editor	15 International Glaciological Society
4 Recent work	15 <i>Journal of Glaciology</i>
4 Austria	17 <i>Annals of Glaciology</i> 56(69)
4 Monitoring of Alpine glaciers	18 <i>Annals of Glaciology</i> 56(70)
7 Tropical glaciers	18 <i>Annals of Glaciology</i> 57(71)
7 Arctic	19 Report from the Nordic Branch Meeting, October/November 2014
8 Antarctica	24 News
9 Ice caves	24 Obituary: Charles Swithinbank 1926–2014
9 Remote sensing	27 Obituary: Robert H Thomas 1937–2015
10 Applied glaciology	32 Glaciological diary
10 Glacier hydrology	36 New members
11 Permafrost/Rock glaciers	
12 Glacier modelling	
12 Ice–atmosphere interactions	
13 Ecology/Biology	
13 Other	
13 Databases	
14 Abbreviations	

Cover picture: Fox Glacier, New Zealand. Photograph by Brad Parsk.

EXCLUSION CLAUSE. While care is taken to provide accurate accounts and information in this Newsletter, neither the editor nor the International Glaciological Society undertakes any liability for omissions or errors.

From the Editor

Dear IGS member

Since the last issue of ICE came out, we have witnessed the devastating earthquake in Nepal. It was particularly poignant for the IGS as we had very recently had a very successful and enjoyable symposium in Kathmandu. We met up with old friends and made new ones. We enjoyed the fantastic hospitality of the local people and we got to see some fantastic sights. So it was a great shock to us to hear of the devastation and loss of life; for several days we were worrying about the safety of colleagues and friends. It was a relief to see them slowly declaring themselves safe on a Facebook page set up for that purpose.

As more and more images appeared it was heartbreaking to see how the lovely places we had visited had been reduced to rubble. Where we had been sitting with some wonderful buildings in the background we could now see the same viewpoint but nothing but rubble and destruction.

It was comforting to see the glaciological community rally around and provide some valuable support using their expertise to evaluate the situation and analyse potential hazards and doing what they do best to use their specialised skills and knowledge of modern technology to help their fellow human beings move towards a safer community. Some individual glaciologists and environmental organisations started to collect funds in an effort to alleviate the pain and suffering of the Nepalese people. May that effort long continue and I am already looking forward to the next IGS symposium in Nepal in some years time when we will learn about the rebuilding of the country we had come to love so dearly.

But let us move closer to home. The IGS has been working hard moving towards Gold Open Access. Several members have taken part in this effort and we are beginning to see and evaluate the various options for moving forward. We hope that during the IGS Annual General Meeting planned for the Cambridge symposium we will be able to present members with some choices. One thing is certain: the IGS will be going through some important changes, which hopefully will benefit both our

members and the glaciological community as a whole. You can expect to see some of these changes being implemented at the beginning of next year.

Things are already happening on other fronts. All our archive issues dating back to 1947 are being converted to XML and members will soon be able to view those old papers using modern techniques and display platforms. We will be moving all IGS publications to one common point of access, be it the very latest papers or the oldest. We will of course be producing all new papers as PDFs and also as XML which can then be funnelled through various templates in order to optimise the viewing of all articles, according to your viewing platform, be it a large-screen monitor, a tablet or smartphone or even a Kindle. In addition, we are planning a complete revamp of our website and to introduce new features that we trust will be a benefit to our members and the whole glaciological community.

To finish off, let me tell you where we are at in the publishing

<i>Journal</i> 227 (June)	<i>Annals</i> 70
- 14 papers online	- 21 papers accepted
- further 2 typeset	- 19 papers online
	- 1 more typeset
<i>Journal</i> 228 (July/ August) and 229 (September/October)	- 2 more being revised
- 18 accepted	<i>Annals</i> 71
- 6 typeset	- 15 papers accepted
<i>Annals</i> 69	- 2 papers online
- 47 papers accepted	- 5 more typeset
- 45 online	- 30 under review
- 2 more typeset	- 48 rejected
- 3 other possibles	<i>Annals</i> 72
	- 26 papers submitted

We are getting a steady stream of papers submitted, on a par with previous years.

But the really enjoyable news is that our membership is the highest it has ever been and we are very optimistic in breaking the 1000 barrier in the not so distant future.

Magnús Már Magnússon
Secretary General

Assistant Professor (Tenure Track) of Glaciology

→ The Department of Civil, Environmental and Geomatic Engineering (www.baug.ethz.ch) at ETH Zurich and the Swiss Federal Institute for Forest, Snow and Landscape Research, WSL (www.wsl.ch) invite applications for the above-mentioned assistant professorship.

→ The assistant professor will lead a research group to be shared between the Department of Civil, Environmental and Geomatic Engineering at ETH Zurich and the Swiss Federal Institute for Forest, Snow and Landscape Research, with a strong research focus on alpine glaciology. The new assistant professor will be expected to teach undergraduate and graduate level courses, to maintain an active research programme, and to contribute to the departmental service. The research group will be located at the Laboratory of Hydraulics, Hydrology and Glaciology at ETH campus Höggerberg in Zurich as well as at the Swiss Federal Institute for Forest, Snow and Landscape Research in Birmensdorf.

→ The successful candidate should hold a doctoral degree in civil or environmental engineering or a related discipline and should have expertise in physical glaciology. Relevant research areas include, but are not limited to, dynamic behavior of mountain glaciers, sub-glacial processes, fracture growth and mechanical failure in glacier ice, glacier hazards and climate-glacier interactions. We are particularly interested in individuals who combine acquisition and interpretation of data with theoretical work. The development and use of numerical models (e.g. ice flow, ice fracturing, glacier hydraulics) to combine research and engineering problems with observations is also a desired research direction. The selected candidate should establish an attractive teaching programme and must be committed to excellence in education, as well as promote, execute and apply modern teaching methods.

→ The new assistant professor will be expected to teach undergraduate level courses (German or English) and graduate level courses (English).

→ This assistant professorship has been established to promote the careers of younger scientists. The initial appointment is for four years with the possibility of renewal for an additional three-year period and promotion to a permanent position.

→ **Please apply online at www.facultyaffairs.ethz.ch**

→ Applications should include a curriculum vitae, a list of publications, and a statement of future research and teaching interests. The letter of application should be addressed to the **President of ETH Zurich, Prof. Dr. Lino Guzzella**. **The closing date for applications is 30 September 2015**. ETH Zurich is an equal opportunity and family friendly employer, and is further responsive to the needs of dual career couples. We specifically encourage women to apply.



Recent work

Austria

MONITORING OF ALPINE GLACIERS

Long-term monitoring of length changes of Austrian glaciers

Andrea Fischer (OEAV)

Since 1891, the length changes of Austria's glaciers have been monitored regularly. The results are published in the journal of the Austrian Alpine Club. Currently about 100 glaciers are surveyed annually. On Pasterzenkees, Hintereisferner and in the Ankogel Group, ice flow velocities and thickness changes have been measured.

<http://www.alpenverein.at/portal/museum-kultur/gletschermessdienst/index.php> (German only)

Long-term mass-balance monitoring on Austrian glaciers

Long-term glacier monitoring has been continued. Hintereisferner (Oetztal Alps, Austria) is still one of the Austrian benchmark glaciers. Its mass balance has been monitored by IMGI and HDT using the direct glaciological method since 1953. The Austrian glacier monitoring has been considerably extended; mass balance studies are supplemented by ice velocity, ice thickness and length measurements. Additionally, meteorological stations and precipitation measurement networks in the vicinity of these glaciers as well as energy balance/boundary layer studies above the glacier surface have been carried out. Details concerning the different glaciers are found below:

Glacier mass-balance studies Hintereis- and Kesselwandferner, Ötztal Alps, Austria

Rainer Prinz, Stephan Galos, Georg Kaser, PI (all IMGI)

The long-term glacier mass balance series of Hintereis- and Kesselwandferner (since 1953) are being continued in cooperation with the HDT by applying the glaciological method. Results are reported to the WGMS. In addition, one to two ALS per year are available since 2001 (from IGI) and comparison studies are under way.

<http://imgi.uibk.ac.at/research/ice-and-climate/projects/hef>

Measurements of flow velocity at Kesselwandferner and Hochebenkar rock glacier, Ötztal Alps

Martin Stocker-Waldhuber, Lea Hartl, Heralt Schneider (all VGG)

The ice-flow velocity of Kesselwandferner has been measured since 1964/65 by using a number of stakes, so that horizontal and vertical components of ice

flow velocity can be calculated. Kesselwandferner advanced in the late 1970s and early 1980s; the maximum ice flow velocities reached more than 100 m a^{-1} at that time, decreasing to a few meters per year today. The time series of flow velocities at Äusseres Hochebenkar rock glacier started as early as 1937. In contrast to the velocity record at Kesselwandferner, which showed a significant velocity decrease, the Hochebenkar rock glacier accelerated during recent years.

<http://www.gletscher-klima.at> (German only)

Glacier change monitoring in the Hohe Tauern Range

Heinz Slupetzky (HDS and US), Hans Wiesenegger (HDS)

2014 was the 50th year of continuous mass balance measurements on Stubacher Sonnblickkees. With extrapolations, the series starts in the year 1959. 3-D terrestrial laser scanning allows the production of DTMs which give a documentation of the rapidly changing topography. A main goal in recent years was to secure the continuation of the series in face of the withdrawal of Heinz Slupetzky, who has conducted the mass balance measurements since 1963. Therefore two automatic cameras were installed by the HDS. US/IFFB agreed to take over the responsibility for the measurements in cooperation with HDS. A collaboration between HDS and IGF focusses on digitizing of the collected material of the glaciological investigations since 1960 and to make it partly available via PANGAEA. The collection of Heinz Slupetzky was moved from FGGUS to the HDS into an archive. The runoff of a major part of the Stubacher Sonnblickkees is recorded at the outlet of the Unterer Eisboden Lake (HDS). The water balance in the catchment area of the reservoir Weißsee – with the Stubacher Sonnblickkees – has been estimated every year. At the Obersulzbachkees in the western Hohe Tauern the runoff has been recorded at the hydrological station Kees-Obersulzbach (HDS) since 1988 and in 2009 a new runoff station was built and was named 'Tuerkische Zeltstadt'; the catchment area is considerably (~55%) glacierized. The long-term series of ice velocity measurements (FHNB, US) on the Oedenwinkelkees, Hohe Tauern Range, Austria, has been continued with re-surveys every 2 years in recent years. Since only small changes have been observed the measuring interval will be 3 years in future. At present, the measurements

are under the responsibility of IGF. Heinz Slupetzky finished the glacier length measurements in the Hohe Tauern Range, mainly in the Stubach Valley, within the long-term monitoring of length changes of Austrian glaciers of the OEAV, which he carried out as principal investigator from 1960 (the first years together with Werner Slupetzky).

Mass balance monitoring at Langenferner, Italian Alps

Stephan Galos (IMGI), Rainer Prinz (IMGI), Georg Kaser (IMGI) and Roberto Dinale (HAB)
Langenferner is a small valley glacier with an area of 1.65 km² (2012), located at the head of the Martell Valley in the Ortles-Cevedale Group. The glacier spans from 3390 to 2710 m, an altitudinal range representative for glaciers of the region. Langenferner has been subject to detailed glaciological observations performed by the IMGI in close collaboration with the HAB since the hydrological year 2003/04. Mass balance data are reported to the WGMS. Apart from the application of the fixed date direct glaciological method resulting in winter, summer and annual mass balances, the geodetic method is applied using repeated airborne laser-scanning data. Meteorological conditions are recorded at several weather stations in the vicinity of the glacier maintained by the HAB. Two new weather stations on the glacier surface facilitate detailed studies on the energy balance and thus allow a sophisticated meteorological and climatic interpretation of the direct glaciological measurements.
<http://imgi.uibk.ac.at/research/ice-and-climate/projects/langenferner>

A regional network for monitoring the glaciers of Vinschgau, South Tyrol, Italy

Stephan Galos (IMGI), Christoph Klug (IGI), Lorenzo Rieg (IGI), Rudolf Sailer (IGI) and Roberto Dinale (HAB), Georg Kaser (IMGI; PI)
Additionally to the ongoing detailed mass balance programme at Langenferner, a regional observational network for the glaciers has been established in the Vinschgau, an inner Alpine valley characterized by low precipitation amounts and intensive agriculture relying on irrigation. To evaluate the glacier melt contribution to total river discharge within the study region, a physically based energy and mass-balance model will be developed at Langenferner and transformed to the catchment-scale. Hence, ablation stakes have been installed at nine glaciers in the study region (the northern part of the Ortles-Cevedale Group and the southern part of the Ötztal Alps). Furthermore, data from ALS campaigns are used to investigate current (2005–13) changes in area and volume of all glaciers in the region.
<http://imgi.uibk.ac.at/research/ice-and-climate/projects/vinschglac>

Measurements of ablation and ice flow velocities on the glacier tongues of Taschachferner and Gepatschferner

K. Helfricht (alpS), K. Schneider (alpS), M. Stocker-Waldhuber (IGF), M. Kuhn (IMGI)

Ablation stakes are monitored on the glacier tongues of Taschachferner and Gepatschferner (Ötztal Alps, Tyrol, Austria). Initially, three ablation stakes were drilled on each glacier tongue in 2009. On Gepatschferner the number of stakes was increased to 20 in 2012. Ablation amounts are determined three to six times within one ablation season. Displacements of the stakes are recorded using DGPS.

Project: H03 MUSICALS_A, alpS

PROSA: PAK 736/1, SCHM 472/17-1 (K.-H. Schmidt) & I894-N24 (M. Kuhn)

Pasterze Glacier: Glacial, proglacial, and paraglacial monitoring at the largest glacier in Austria

Gerhard Karl Lieb (UniGraz), Andreas Kellerer-Pirklbauer (UniGraz), Michael Avian (TU Graz/UniGraz), Viktor Kaufmann (TU Graz), Ruth Drescher-Schneider (Kainbach/Graz)

Glaciological research at Pasterze Glacier, at about 17 km² the largest glacier in Austria, has been carried out by members of the University of Graz since the 1950s. About 10 years ago, members of the Graz University of Technology joined these research activities. Relevant projects at Pasterze Glacier have been funded recently for instance by the Austrian Science Fund (FWF) (ALPCHANGE), the European Union (PermaNET), and the Austrian Academy of Sciences. Several different techniques have been applied since then to understand glacial but also proglacial and paraglacial processes and dynamics. Apart from the annual glaciological campaign at Pasterze (carried out within the glacier monitoring program of OEAV), different spaceborne, airborne and terrestrial remote sensing approaches (SAR-Interferometry, airborne laser scanning, terrestrial laser scanning, aerial photogrammetry, GPS, DGPS, tachymetry) have been used for glacier monitoring (quantifying changes in volume, velocity and glacier terminus) but also for detecting morphological changes in the recently deglaciated areas (proglacial landscape dynamics) as well as adjacent rock faces (paraglacial rock slope adjustments). Another research focus at Pasterze Glacier is the pronounced supraglacial debris cover regarding evolution, characteristics, thermal regime and effect on ablation. Related to the receding glacier, organic material (peat lumps, wood fragments) has been retrieved and investigated (partly in cooperation with University of Innsbruck; Kurt Nicolussi) in the proglacial

area, further deciphering the Holocene landscape dynamics of the large ice mass. Finally, also the morphological effects of ice avalanches at an adjacent glacier (in cooperation with US; Heinz Slupetzky) have been studied recently.

Glacier monitoring in the Schober mountains, Hohe Tauern range, Austria

Gerhard Karl Lieb (UniGraz), Andreas Kellerer-Pirklbauer (UniGraz), Michael Avian (TU Graz/UniGraz), Viktor Kaufmann (TU Graz), Michael Krobath (UBZ Graz)

Glaciers in the Schober Mountains are small (largest ca. 0.75 km²) and characterized by a pronounced supraglacial debris cover. Furthermore, rock glaciers (as surface expressions of mountain permafrost) and permafrost are widespread and therefore interesting glacier-permafrost relationships exist in this mountain range. In particular since the onset of the ALPCHANGE project in 2006, different methodical approaches as described in the previous section (remote sensing, ground temperature monitoring, sedimentological studies) as well as climatological and geophysical measurements have been applied in order to gain a better understanding of glaciers, rock glaciers, and permafrost. The research was carried out within the projects ALPCHANGE, PermaNET, permAfrost and several smaller projects.

Research related to permafrost and periglacial processes:

(<http://ipa.arcticportal.org/reports-2011/672/598.html>) Contact: Andreas.kellerer@uni-graz.at

Mass-balance measurements on Mullwitzkees, Hohe Tauern

M. Stocker-Waldhuber (IGF), A. Fischer (IGF)
Mullwitzkees is situated in the Hohe Tauern massif within the core zone of the Hohe Tauern National Park. It is exposed to the south and covers an area of approximately 3 km². Direct measurements of winter and summer mass balance were started in 2006 including ca. 13 ablation stakes, 3 snow pits and measurements of precipitation and temperature. The project is funded by the Hohe Tauern National Park and the HDT.
martin.stocker-waldhuber@uibk.ac.at

Glacier monitoring of Venedigerkees

Bernd Seiser, Hans Wiesenegger, Christian Mitterer (IGF)

At the forefield of the former Obersulzbachkees in Hohe Tauern, the Hydrographical Survey of Salzburg (HDS) installed a hydrological monitoring device with a runoff gauge. Two years ago, direct and indirect measurements of mass balance at the easternmost tributary to the former Obersulzbachkees glacier system, the Venedigerkees, were added. The direct mass

balance measurements are complemented by a network of automatic cameras that monitor the receding snow cover.

www.mountainresearch.at

Mass balance of Hallstätter Glacier, Dachstein massif

Lea Hartl (IGF), Martin Stocker Waldhuber (IGF), Klaus Reingruber (BS)

The mass balance monitoring at Hallstätter Glacier is a follow-up project of the first glacier monitoring done by Simony in the mid-19th century at the so-called Karls-Eisfeld. This mass balance series is the eastern- and northernmost glacier monitoring series in the Eastern Alps and is sponsored by the Hydrological Service of the Upper Austrian Federal Government and the Energie AG company.

www.dachsteingletscher.info (German only)

Mass balance measurements on Jamtalferner, Silvretta

Andrea Fischer (VGK)

Jamtalferner in the Silvretta is the westernmost Austrian glacier with annual time series of direct mass balance measurements. Monitoring started in 1988/89 and includes approximately 20 ablation stakes, 6 snow pits, winter and summer balance as well as precipitation measurements. The nearest weather station was located in the village of Galtür, since autumn 2013 a new automatic weather station (AWS) has been operating next to the Jamtal hut, maintained by the Avalanche Warning Service and the Hydrological Survey of the Tyrolean Government (HDT).

www.gletscher-klima.at (German only)

The Eiskarglacier in the Carnic Alps

Gerhard Hohenwarter (ZAMG)

The Eiskar-Glacier (2200 m a.s.l.) - the southernmost glacier in Austria - is embedded in a cirque of the north face of Kellerwand in the Carnic Alps. Since 1992, the Eiskar has been part of the official glacier monitoring program of the Austrian Alpine Club (OeAV) with annual measurements. Additional to the annual length measurements, which have shown no significant change since 2008, the thickness of the glacier was measured with Geo-RADAR in 2010. Although the glacier covers an area of only 0.16 km², an ice thickness of up to 50 m is reached. In contrast to the large glaciers in the Alps this small glacier is fed by avalanches. Therefore winter precipitation is highly important. In order to estimate winter accumulation, an automatic weather station (AWS) has been installed in autumn 2011, which measures snow height, air temperature, relative humidity, wind speed, and wind direction. In the last three winters, the

station collected data continuously. However, since February 2014 no data are available because the weather station had been completely covered by snow since then. Unfortunately, the beginning of the melt season revealed that the AWS has not survived the last winter with extraordinarily high accumulation (mean value: 8-9 m snow height, max: 13 m!). Preparations for mass balance measurements have been going on since 2011. So far, this project could not be realized due to lack of financial resources. The Eiskar-Glacier, as an example for a low level cirque glacier fed by avalanches in the Southern Alps, had a small mass loss, but no significant decrease in length in the last 6 years. In the last 100 years, only two more winter periods were found that had similarly large amounts of precipitation as the winter 2013/14. Thus a positive mass balance and another year with no length change can be expected for the year 2014.
Contact: Gerhard.Hohenwarter@zamg.ac.at

TROPICAL GLACIERS

Atmospheric observations and glacier mass balance modelling in the Cordillera Blanca, Peru Wolfgang Gurgiser, Ben Marzeion, Marlis Hofer, Martin Großhauser, Stephan Galos, Georg Kaser (PI) (all IMGI)

During the past years, automatic weather stations have been operated at three glaciated catchments in the Peruvian Andes. The high-resolution data have been used for statistical downscaling and are generally useful for developing methods to link atmospheric conditions in the boundary layer to atmospheric model data or satellite observations. For one study site (Shallap Glacier), AWS data and stake readings (evaluation) have been used to model spatial distributed glacier mass balance with a process based model at high temporal resolution. The results were used as reference to test mass balance models of low complexity.

Vulnerability to water scarcity and glacier fed water availability in the tropical Callejón de Huaylas, Peru

Wolfgang Gurgiser (IMGI), Kathrin Schneider (IGH), Georg Kaser (IMGI),/Martina Neuburger (IGH) Co-Pis

Runoff from glaciers is the dominant contributor to river discharge in the tropical Cordillera Blanca, Peru, during the dry season. In a joint effort, glaciologists and social geographers aim at identifying present-day and potential future discrepancies between water availability and water demand as experienced differently by different user communities along a tributary valley of the Rio Santa, Cordillera Blanca, Peru.

Measuring penitentes with an Xbox Kinect

Lindsey Nicholson (IMGI) and Shelley MacDonell (CEAZA, Chile)

Penitentes, which are spikes of snow or ice that can reach several metres in height, are widespread in the semi-arid Andes. Measuring penitentes is problematic due to the difficult access and complex surface topography, and without good measurements it is difficult to evaluate how well existing mass and energy balance models perform over penitentes. Funded by a National Geographic Waitt Grant this research aims to test the performance of the Xbox Kinect sensor as a mobile means of generating high resolution digital terrain models of penitentes fields and their change through time.

Contact: lindsey.nicholson@uibk.ac.at

Multi-scale analyses of the climate-glacier relationship on tropical Lewis Glacier, Mount Kenya, East Africa

Lindsey Nicholson, Rainer Prinz, Georg Kaser (PI) (IMGI)

Since September 2009 an automatic weather station (AWS) has been operating near Lewis Glacier on Mt. Kenya at an altitude of 4800 m. Together with historical and recent mass balance observations this is the basis to force, optimize and validate process-based physical energy, mass balance and limited area climate models to understand drivers, processes and impacts of glacier changes at various scales. Combining this with results from recent studies on nearby Kilimanjaro glaciers has the potential for revealing a sophisticated history of the climate in the tropical mid-troposphere, where routine meteorological measurements are very rare.

<http://imgi.uibk.ac.at/research/ice-and-climate/projects/kenya>

ARCTIC

Svalbard glaciers and climate change (SvalGlac)

Friedrich Obleitner (PI, IMGI) , Tobias Sauter (IMGI)

The project focuses on the energy and mass balance of an Arctic glacier (Kongsvegen, Svalbard) and their interactions with the atmospheric boundary layer. The approach is mainly based on extensive meteorological and glaciological observations and numerical modelling. Simulations are performed in local and spatially distributed modes aiming at better understanding of the seasonal evolution of atmospheric and subsurface exchange processes and the associated response of the glacier to changes of the meso-scale atmospheric conditions. This also considers the skill of different meteorological data sets and

methods to derive spatially distributed data for initialisation and forcing of snow/ice energy balance models. The effort is supported by investigation of the distribution and structure of snow across the glacier, which is of particular importance for investigation of processes related to e.g. snow redistribution or internal refreezing and their impact on the energy and mass balance of the glacier. The project is embedded in an international research network focusing on the sensitivity of Svalbard glaciers to climate change. **Funding:** FWF – Fonds zur Förderung der wissenschaftlichen Forschung (grant I 369-B17); ESF – European Science Foundation (PolarClimate); Österreichische Gesellschaft für Polarforschung (Julius-Payer-Stipendium 2010); Wissenschaftlich-Technisches Abkommen mit Frankreich 2014-15 (grant FR 10/2014). Duration: 2010 - 2014
<http://imgi.uibk.ac.at/research/atmospheric-dynamics/projects/svalglac> ; www.svalglac.eu

Mass balance monitoring Freyaglacier (NE-Greenland)

Wolfgang Schoener, Bernhard Hynek (ZAMG)
 Freyaglacier is a 7 km² large valley glacier in Tyrolerfjord (NE-Greenland) on Clavering Island in short distance to the Danish Zackenberg research station. A mass balance monitoring was initiated as part of the Austrian contribution to the International Polar Year in 2007/08, with the aim to better quantify the reaction of Greenland marginal glaciers to climate change. First measurements of mass- and energy balance at Freyaglacier were carried out already within the pioneering work of H.W. von Ahlmann in the late 1930s, unfortunately stopped by World War 2. The direct glaciological method is used for estimating the annual balance of the glacier based on a network of ablation stakes and measurements of accumulation using GPR, depth sondes and snow pits. In some years it was also possible to measure the winter balance of the glacier. In summer 2011 the observations were improved through installation of an automatic weather station (AWS) at the glacier. Currently, Freyaglacier and the nearby A.P. Olsen Ice Cap (measured by GEUS) are the only sites with direct observations of glacier mass balance in NE-Greenland.

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Mass balance modelling at Freya glacier (NE-Greenland)

Ulrich Strasser (IGI), Thomas Marke (IGI), Florian Hanzer (alpS)

With the central aim to investigate climate change impacts on Freya glacier, a small valley glacier in NE-Greenland, a distributed, physically based snow-hydrological energy and mass balance

model (AMUNDSEN) has been set up and appropriately parameterized for the simulation of the local glacier energy and mass balance. These modelling efforts have been carried out in close cooperation with the Central Institute for Meteorology and Geodynamics (ZAMG) in Vienna and complement a monitoring programme that has been initiated by the ZAMG in the International Polar Year 2007. In the framework of expeditions carried out as part of the projects Glacier-MEMO (Glacier and Mass and Energy Balance Modelling at Freya Glacier) and FreyEx (The Freya Glacier Experiment), automatic weather stations have been installed on the glacier surface and in its vicinity, increasing the amount of meteorological information at the study site. Using these data within numerical modelling experiments, the regionalisation of meteorological point observations as well as the simulation of the glacier mass balance could be significantly improved.

Detection of GLOF trigger mechanisms from seismic and GPS monitoring (AP-Olsen Ice Cap, NE-Greenland)

Daniel Binder, Wolfgang Schoener (ZAMG)
 The ice-dammed lake at the A.P. Olsen Ice Cap (NE-Greenland) represents an ideal site for process-orientated studies of GLOF dynamics under cold-based glacier hydrology due to the excellent logistics of the nearby Zackenberg research station (74°28'N, 20°34'W). An ice-free side valley is blocked by the South-East outlet glacier of AP Olsen Ice Cap; impounded waters from precipitation and melt processes form a classic marginal, ice-dammed lake, which currently exhibits annual outburst floods. Since the glacial stream drains into the Zackenberg River, the Zackenberg Research Station is directly affected by the outburst floods. In 2012 a simultaneous GPS and passive seismic network was installed in order to identify fundamental relations between the observed surface kinematics, en- and subglacial processes and features before and during the outburst floods. As a first result, an impressive outburst in August 2012, which was observed on-site during a field trip, was well documented by the network.
 Contact: daniel.binder@zamg.ac.at, wolfgang.schoener@zamg.ac.at,

ANTARCTICA

Stable isotopes and precipitation regime at Antarctic deep drilling sites

E. Schlosser (IMGI), A. Dittmann (IMGI)

For a correct palaeoclimatologic interpretation of stable water isotopes from ice cores the atmospheric processes that determine moisture transport and precipitation formation and their role for isotope

fractionation have to be better understood. At the deep ice core drilling site 'Dome C', East Antarctica, fresh snow samples have been taken since 2006. These samples have been analysed crystallographically, which enables us to clearly distinguish between blowing snow, diamond dust, and 'synoptic precipitation'. Also the stable oxygen/hydrogen isotope ratios of the snow samples were measured, including measurements of ^{17}O . This is the first and only multi-year fresh-snow data series from an Antarctic deep drilling site. The Antarctic Mesoscale Prediction System (AMPS) employs Polar WRF for aviation weather forecasts in Antarctica. Precipitation at Dome C is temporally dominated by diamond dust. However, comparatively large amounts of precipitation are observed during several 'high-precipitation' events per year, caused by synoptic activity in the circumpolar trough and related advection of relatively warm and moist air from lower latitudes to the interior of Antarctica. AMPS archive data are used to investigate the synoptic situations that lead to 'high-precipitation' events at Dome C; in particular, possible moisture sources are determined using back-trajectories. With this meteorological information, the isotope ratios are calculated using two different isotope models, the Mixed Cloud Isotope Model, a simple Rayleigh-type model, and the LMDZ-iso (Laboratoire de Météorologie Dynamique Zoom), a General Circulation Model (GCM) with implementation of stable isotopes. The results are compared to the measured stable isotope ratios of the fresh snow samples.

Cooperation: NCAR (National Center for Atmospheric Research), Boulder, CO, USA, LSCE (Laboratoire des Sciences du Climat et de l'Environnement), Gif-sur-Yvette, France, University of Trieste, Italy.

Funding: FWF (Austrian Science Fund) (P24223) <http://imgi.uibk.ac.at/research/iceclim/polar-meteorology>

ICE CAVES

Austrian ice caves (AUSTRO*ICE*CAVES*2100)

Christoph Spötl (PI, Inst. of Geology Innsbruck), D. Wagenbach (Heidelberg Academy of Sciences), B. May (Heidelberg Academy of Sciences), F. Obleitner (IMGI), W. Schöner and G. Weyss (ZAMG), M. Behm (Technical University Vienna), R. Pavuza (Museum of Natural History, Vienna), A. Rettenbacher (Eisriesenwelt GmbH)

The Eastern Alps host a great number of spectacular underground glaciers, which are among the largest of their kind on Earth and some of which are top tourist attractions. The fate of these ice caves in a warming world is unknown, but

documentary evidence shows a large reduction in ice since the end of the 'Little Ice Age', i.e. since the second half of the 19th century. Recognizing the urgency of this matter, this multi-disciplinary pilot study focussed on dynamically ventilated ice caves and attempted to (a) gain a better physical understanding of underground ice dynamics, (b) to develop constraints on the fate of alpine ice caves, and (c) to assess the unexplored potential of this ice as a paleoclimate archive in the Alps. Extensive observations have been performed in one of the largest ice caves cut in Triassic limestones of the western edge of Tennengebirge (Eisriesenwelt, Salzburg) and related results have been collected in a special issue of The Cryosphere (TC).

Funding: Austrian Academy of Sciences, research program Alpenforschung

Duration: 2006-2009

<http://quaternary.uibk.ac.at/Research/Current-Research/Climate-of-the-past-cave-deposits/Ice-Caves.aspx>

REMOTE SENSING

Remote sensing of glaciers, ice sheets and seasonal snow

Helmut Rott, Thomas Nagler, Gabriele Bippus, Ursula Blumthaler, Markus Hetzenecker, Petra Malcher, Elisabeth Ripper, Roman Sandner, Kilian Scharrer, Karl Voglmeier, Jan Wuite (ENVEO)

Main activities at ENVEO IT GmbH are devoted to the development of methods for retrieval of physical properties of land ice and snow from Earth observation (EO) satellite data, the generation of satellite-based data sets on snow and ice parameters, and the application of these data for studies of ice dynamics, glacier mass balance, and snow climatology and hydrology. The inversion of EO data is based on in-house developed software for processing of radar (SAR) data and optical imagery. Maps of ice sheet and glacier motion are produced for ESA (European Space Agency) Climate Change Initiative (CCI) projects 'Ice-Sheet CCI' (led by Technical University Denmark) and 'Glacier CCI' (led by Univ. Zürich). In the ESA project GlacAPI 'Multi-sensor analysis of glacier response to climate change on the Antarctic Peninsula', detailed analysis of surface motion, volume change, and mass balance and their temporal changes since ice shelf disintegration are performed for outlet glaciers to Larsen-A and -B embayments. ENVEO is involved in two other ESA projects on Antarctic glaciology, led by University of Leeds: the project 'CryoSat & Cryosphere', studying ice sheet grounding zones with altimeter and SAR sensors, and the project 'Antarctic Peninsula Mass

Balance', aimed at reducing the uncertainty of API mass balance using three different satellite based techniques. Regarding seasonal snow cover, ENVEO contributed to the ESA project GlobSnow (led by Finnish Meteorological Institute), in which multi-year data sets on extent and physical properties of the global snow cover were generated for climate studies. ENVEO has been leading an international team on scientific and methodological developments for a candidate satellite mission of the ESA Explorer Programme, applying a dual frequency (Ku- and X-band) SAR sensor for spatially detailed measurements of snow water equivalent. The activities include theoretical studies on radar signal interaction with snow, development of inversion algorithms for snow parameters, and algorithm validation in field experiments with airborne and ground based radar sensors. In preparation of sustainable EO based snow and ice services, ENVEO leads the Project CryoLand of the 7th Framework Programme of the European Union, in which regional to continental scale products on snow, glaciers, and fresh water ice are generated for specific users as well as for the public.
www.enveo.at

Comparison of snow depths derived from multi-temporal lidar surveys with snow depths calculated from GPR measurements on glacier surface

K. Helfricht (alpS, IMGI), M. Kuhn (IMGI), M. Keuschnig (alpS, DGG US), A. Heilig (CGG BASH, IEP Univ. of Heidelberg)

Surface elevation changes derived from multi-temporal airborne laser scanning (ALS) surveys were compared to snow depths calculated from 35.4 km of ground penetrating radar (GPR) profiles on the four glaciers Hintereisferner, Kesselwandferner, Gepatschferner and Vernagtferner in the Ötztal Alps (Tyrol, Austria). The study aimed to evaluate the effect of the summation of snow densification and ice flow to ALS-derived snow depth on the glaciers in the study area. A Landsat 5 image was used to distinguish between snow covered area and bare ice areas of the glaciers at the end of the ablation season. In present accumulation areas, ALS surface elevation changes differ from snow depths calculated from GPR measurements by -0.4 m on average with a mean standard deviation of 0.34 m. Differences between ALS derived surface elevation changes and snow depths calculated from GPR measurements are distinctly smaller along the profiles conducted in central parts and the tongues of the glacier surfaces with a mean difference of 0.004 m and a standard deviation of 0.27 m.

Project: H03 MUSICALS_A, alpS

APPLIED GLACIOLOGY

Stability of firn overhangs and safety aspects

Heinz Slupetzky (FGGUS), Wolfgang Fellin (IIE), Stefan Ghetta (IIE)

Deposits of snow avalanches from the winter sometimes remain at the end of the summer. The boundaries of these deposits may form overhanging walls due to melting processes. Such walls are attractive for ice climbers to train their skills. Motivated by a deadly accident in 2006, the tensile strength of firn samples collected immediately after the incident was determined. A standard engineering stability model for the maximal overhang of walls loaded by persons climbing at the front side was developed. A review of documented failures and accidents revealed that the collapse of these overhangs were initiated by a damage of the side wall of the overhang in the upper part or on the top of the deposit, i.e. an initial crack in the tensile zone of the structure; sometimes the accidents happened without any apparent external reason. A video documentation of a field test clearly verified the easiness of triggering a collapse by hammering an ice axe into the upper part of a side wall of an overhang, followed by a rapid crack propagation starting from the place where the initial damage occurred. Summarizing all investigations, it can be recommended that when climbing on free standing overhangs at avalanche deposits the following precautions should be taken: the inclination must deviate less than 25 degrees from the plumb line and the structure must not be damaged by using ice axes or crampons on the top or on the side of the firn walls.

GLACIER HYDROLOGY

Improved runoff simulations for glacierized catchments in the Ötztal Alps (Austria) using airborne laser scanning and energy and mass balance modelling

Florian Hanzer, Kay Helfricht, Katrin Schneider (alpS), Ulrich Strasser, Thomas Marke (IGI), Michael Kuhn (IMGI)

Within the alpS/COMET project MUSICALS, the spatial and temporal variations of water, snow and ice resources in the catchments of the Gepatsch reservoir (Ötztal Alps, Austria) and their impact on reservoir inflow were investigated. High-resolution airborne laser scanning (ALS) measurements of the study area were used to derive a set of end-of-season snow water equivalent (SWE) maps. These SWE distributions along with station-based snow depth observations and glacier mass balance measurements were used to calibrate and validate a distributed physically based snow-hydrological energy and mass balance model (AMUNDSEN). Runoff was simulated using a linear reservoir cas-

cade approach. In a follow-up project, climate change scenarios and a glacier evolution model will be utilized in order to apply the model setup for long-term runoff forecasts.

Hydrological modelling of environmental systems.

Karsten Schulz, Hubert Holzmann (Institute for Water Management, Hydrology and Hydraulic Engineering (IWHW), BOKU).

One main focus of the Institute for Water Management, Hydrology and Hydraulic Engineering (IWHW) is hydrological modelling of environmental systems. In this frame, different hydrological model concepts have been applied and developed. For alpine environments the melt process of snow and ice can form a significant balance component and thus has to be considered in the models. Typical applications of hydrological models are (operational) runoff forecasting, impact studies of land use change or climate change. For short term applications a static approach regarding glacier extent can be sufficient, whereas climate change impact studies represent a projection into the future and require dynamic approaches. In the models, predominantly conceptual assumptions are used, where the climatic drivers are precipitation, temperature and radiation. Melt rates are computed by means of index based models (temperature and/or radiation index); mass transport (ice movement) is considered by conceptual transfer between elevation layers. These rather simple concepts are reliable for coarser spatial scales as used in hydrological modelling of river basins. In the future, IWHW also intends to adapt existing concepts for smaller scales, where detailed monitoring data of glaciological processes are required. Therefore co-operations with glaciological experimentalists would be welcome and highly appreciated.

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Uncertainties of future stream-flow scenarios for snow- and ice dominated catchments in the Austrian Alps

Wolfgang Schoener, Bernhard Hynek (ZAMG)

The project aims to compute stream-flow scenarios for glaciated catchment areas in the Austrian Alps through forcing of a hydrological model with climate model runs from Regional Climate Models. Scenario runs cover the period until 2070 for two catchment areas (Goldbergkees and Obere Salzach in the Austrian Alps). In particular the project focusses on quantifying the uncertainty of scenario model runs for the future considering the uncertainties from both hydro-glaciological modelling and climate modelling,

including:

- Uncertainty originating from the temporal changes of degree-day factor as the result of systematic changes of the surface energy balance of glaciers or snow fields (in particular changes of radiation balance)
- Uncertainty originating from temporal and spatial changes of accumulation patterns during winter
- Uncertainty originating from the temporal change of spatial features of the high alpine climate (temperature lapse rate, precipitation increase with elevation, precipitation correction factor)
- Uncertainty originating from temporal changes of glacier size, glacier topography (Volume-area scaling) and glacier elevation.

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PERMAFROST/ROCK GLACIERS

Monitoring of rock glaciers in the Oetztal Alps

Karl Krainer (Inst. of Geology, Univ. of Innsbruck)
The monitoring program on the hydrology of active rock glaciers and permafrost-affected catchments in the Ötztal Alps was continued in 2013 to study the impact of climate change on the discharge pattern and water chemistry in high alpine regions (Project „Permafrost and Climate Change“ of the Austrian Academy of Sciences). The monitoring programme includes discharge measurements at several automatic gauging stations (including water temperature and electrical conductivity) and chemical analyses of water samples from several rock glacier springs (anions, cations, heavy metals). At selected rock glacier springs with extremely high electrical conductivity, water samples were taken daily by using an automatic water sampler from June until October. Modelling of the distribution of permafrost in the Tyrolean Alps (based on the rock glacier inventory and additional data) was also started last year. A detailed analysis of two cores was finished in 2013. The cores were drilled at rock glacier Lazaun in the southern Ötztal Alps (Schnals Valley, South Tyrol, Italy): Analysis included the amount of ice, electrical conductivity, pH, anions, cations, heavy metals, stable isotopes, palynology and radiocarbon-dating (project PERMAQUA, Interreg IV – Italy-Austria).

Cooperations exist with TU Vienna (M. Rogger/G. Blöschl/E. Brückl), ZAMG (H. Hausmann), Office for Geology and Building materials testing, Autonomous Province of Bolzano (V. Mair/K. Lang/D. Tonidandel), and Univ. Innsbruck: Institute

of Botany, (J.-N. Haas), IMGI, (U. Nickus), Institute of Mineralogy and Petrology (R. Tessadri/P. Tropper), Institute of Ecology (H. Thies) and Institute of Geography (R. Sailer/E. Bollmann).

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Permafrostmonitoring Sonnblick

Stefan Reisenhofer, Claudia Riedl, Wolfgang Schoener (all ZAMG)

The Sonnblick Observatory (3105m a.s.l., Austrian Alps) is a research station involved in a series of international observational programmes of the atmosphere, the cryosphere and recently the biosphere. In 2006, the observation of spatio-temporal patterns of permafrost has been started capturing both permafrost at the summit of Sonnblick as well as permafrost in the debris cover of two slopes with different aspect (North and South, with an area of about 1.5 km² for each test field). The monitoring covers measurements in boreholes and at the ground surface by geophysical methods (ground penetrating radar (GPR), seismic measurements) and laser scanning, respectively. Additionally, extensive meteorological measurements are available from the Sonnblick Observatory. First results for the summit area of Sonnblick based on GPR measurements show a thickness of the debris cover of about 2.5 m, of which approximately the uppermost 1.5 m are the active layer (derived from borehole temperatures). From borehole tomography a thickness of joint bedrock with open, probably ice-filled joints, down to a depth of about 9 m was derived. Measurements from the ground surface temperature network from the two slope sites indicate that permafrost is probable in the Sonnblick region at elevations above 2500 m a.s.l. for north-facing slopes and above 2750 m a.s.l. for south-facing slopes.

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GLACIER MODELLING

Global scale glacier mass balance modeling

Ben Marzeion (IMGI), Alex Jarosch (IMGI/U. of Iceland), Marlis Hofer (IMGI), Jonathan Gregory (U. of Reading/Met Office)

During the past years, a simple model for the surface mass balance of glaciers and ice caps was developed. With the objective to be able to reconstruct and project mass balances on any glacier, the calibration procedure relies on the similarity of past climate anomalies experienced by neighbouring glaciers, rather than assuming similar climate sensitivities of neighbouring glaciers. This procedure makes the calibration independent on the existence of direct mass balance observations of the modeled glacier. The

model has been used to reconstruct (based on climate observations and climate reconstruction from GCMs) and project the glacier contribution to sea-level rise, to estimate the equilibrium global glacier mass for a number of global temperature anomalies, and to determine the effect of glacier retreat to higher altitudes, and changing glacier surface areas, on the sensitivities of glaciers to climate change.

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ICE-ATMOSPHERE INTERACTIONS

Modelling of snow cover-atmosphere interactions

Sascha Bellaire, Mathias W. Rotach (IMGI)

The project SAINT (Snow cover Atmosphere INTERactions) aims at providing an improved understanding of snow cover - atmosphere interactions in complex snow covered terrain. By coupling a high-resolution numerical weather prediction model (COSMO) with a high-resolution snow cover model (SNOWPACK) this project also aims at providing a better representation of snow in numerical weather and climate models. Especially the components of the surface energy balance, which has a direct influence on the snow cover evolution, will be measured within the framework of the so-called i-Box project, which comprises a network of high-resolution meteorological stations located in complex alpine terrain. Hence, predicted fluxes (COSMO) will be compared to measured fluxes for validation. Possible benefits of using a complex snow cover model (SNOWPACK) instead of a simplified snow cover model – as currently implemented in COSMO – will be assessed. Winter field campaigns will provide the required field data for validation of such a model chain, which could become a useful operational tool for e.g. avalanche or hydrological warning services.

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SNOWGRID – Operational, spatially-distributed snow cover modeling in Austria

Marc Olefs, Wolfgang Schoener (ZAMG)

A new physically-based and spatially distributed snow cover model is currently in development at the Austrian national weather service ZAMG. The model is driven with gridded meteorological input data of the integrated nowcasting model INCA (8.1 – 17.7°E; 45.8 – 49.5°N) that uses remote sensing and radar data as well as ground observations and is operated by ZAMG. Additional data from remote sensing and ground measurements are used to validate and calibrate the model output consisting mainly of snow height and snow water equivalent maps in a spatial resolution of 100 m and a time resolution of 15 minutes in near real-time. Its energy balance mode contains partly newly

developed schemes (e.g. radiation, cloudiness) based on high quality solar and terrestrial radiation data, satellite products and ground measurements. Snow physical properties and snow cover dynamics are currently incorporated in the model based on a simple 2-layer scheme, as the primary focus of the model are fast calculations on the large grid and to accurately represent the spatial distribution of the snow mass and depth (and not its detailed microstructural behavior), which is of great interest for authorities and the general public. Snow extent from SNOWGRID together with satellite data is also used to evaluate the effect of initializing a numerical weather prediction model such as AROME (high resolution weather forecast model) using a real snow distribution instead of climatological estimates as it is operationally done. The snow model is developed in close collaboration with regional avalanche warning centers and practitioners.

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Empirical-statistical downscaling for data-sparse, glaciated mountain ranges

Marlis Hofer (IMGI), Ben Marzeion (IMGI), Stephan Galos (IMGI), Thomas Mölg (IMGI, Technische Universität Berlin)

During the past few years, an empirical-statistical downscaling (ESD) framework for data-sparse, glaciated mountain ranges was developed. The goal of the ESD framework was to correct data available by large-scale atmospheric models (here, reanalysis data), to better account for local-scale atmospheric variability at, or near mountain glaciers. Since observations are generally sparse for glaciated mountain sites, the major challenge was to establish statistically significant ESD transfer functions based on the small observational records. The ESD framework was applied to daily and sub-daily time series of air temperature, and specific humidity, measured at several automatic weather stations in the Cordillera Blanca (Peru). The ESD model skill showed high interannual variations, with higher values during the wet season, than during the dry season. ERA-interim reanalysis data by the ECMWF outperformed several other global reanalysis data sets as predictors.

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ECOLOGY/BIOLOGY

Biological activity in glacier ice

Birgit Sattler, Philipp Larch, Barbara Post, Klemens Weisleitner, Jakub Zarsky (all IEI)

During the past years, various glaciers in Arctic, Antarctic and Alpine regions have been investigated for biological activity on supraglacial habitats. Glaciers can be considered as hot

spots for mainly microbial communities but also metazoans such as springtails or tardigrades. Cryoconite holes resemble mini lakes and harbor a variety of organisms, which can show activities comparable to temperate soils despite harsh living conditions. To assess the ecological potential of glaciers, superficial measurements can give assumptions about organic production on a global scale. To achieve a higher resolution of data a non-invasive instrument has been developed called L.I.F.E. (laser induced fluorescence emission) to quantify photosynthetic active pigments on glacial surfaces.

In englacial systems which are accessible - such as the Natur Eispalast at Hintertuxer Glacier – photosynthesis takes place under artificial light sources that are responsible for the growth of so called Lampenflora consisting mainly algae, ciliates and bacteria of airborne origin or by introduction via melt water. Under the concept of Sparkling Science projects, where universities and schools are bridged, school kids are included in field work on glaciers.

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OTHER

Mass exchange and motion of glacier tongues and subglacial sediments, under present conditions and conditions of ongoing rapid deglaciation

M. Stocker-Waldhuber (IGG Halle, IGF, IMGI), M. Kuhn (IMGI), K. H. Schmidt (IGG Halle), D. Morche (IGG Halle)

With the purpose to detect glacial and subglacial mass exchange including the erosion of the bedrock of the Gepatschferner, direct and indirect glaciological and geodetic methods are conducted. These measurements belong to the subproject 'Glaciology and Geomorphology', which is part of the DFG/FWF joint project PROSA (Proglacial Systems of the Alps). Within this project all relief changes within the catchment of the river Fagge including Gepatschferner and Weißseeferner down to the beginning of the backwater of the Gepatsch reservoir (Ötztal Alps) are being investigated.

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DATABASES

3P Clim

Andrea Fischer (IGF), Bernd Seiser (IGF)

The Interreg project 3P Clim aims at combining climate and glacier data for the regions of Tyrol, Bozen (Bolzano), and Veneto in an online map. It will include basic topographic information for all glaciers of the regions, and for some glaciers

also time series of length changes and actual and historical images.

www.mountainresearch.at

Glaciological data base Tyrol/Salzburg

Andrea Fischer (VGK)

The provinces of Tyrol and Salzburg have a long history in glaciological research. The majority of the data collected since the first image of a glacier was drawn in 1601 is currently not digitally catalogued, except for the most recent data. Within this project, data are searched for, listed, summarized, and published at the data base of AWI, www.pangaea.de.

www.gletscher-klima.at (German only)

ABBREVIATIONS

ALS	Airborn Laser Scanning
alpS	Centre for Climate Change Adaptation
AMPS	Antarctic Mesoscale Prediction System
AMUNDSEN	Alpine Multiscale Numerical Distributed Simulation Engine
API	Antarctic Peninsula
AWS	Automatic Weather Station
BOKU	Univ. of Natural Resources and Life Sciences
BS	BlueSky Wetteranalysen
CCI	Climate change initiative
CEAZA	Centro de Estudios Avanzados en Zonas Áridas
CGG BASH	Commission for Geodesy and Glaciology, Bavarian Academy of Sciences and Humanities
COSMO	Consortium for Small-scale Modeling
DFG	Deutsche Forschungsgemeinschaft
DGGUS	Department of Geography and Geology, University of Salzburg
DGPS	Differential GPS
DTM	Digital Terrain Model
ENVEO	Environmental Earth Observation Information Technology GmbH, Innsbruck
ESA	European Space Agency
ESD	Empirical-statistical downscaling
ESF	European Science Foundation
FGGUS	Fachbereich Geographie und Geologie, Universität Salzburg
FHNB	Fachhochschule Neubrandenburg, Germany
FreyEX	Freyja Glacier Experiment
FWF	Austrian Science Fund
GCM	General Circulation Model
GEUS	Geological Survey of Denmark and Greenland

MEMO	Mass and Energy balance Modelling
GLOF	Glacier lake outburst flood
GPR	Ground-penetrating radar
GPS	Global Positioning System
HAB	Hydrology Department of the autonomous province of South Tyrol, Italy
HDS	Hydrological Survey of Salzburg
HDT	Hydrological Survey of Tirol
IEI	Inst. of Ecology, University of Innsbruck
IEP	Institute of Environmental Physics, University of Heidelberg
IFFB	IFFB Geoinformatik-Z_GIS, University of Salzburg
IGF	Institute for Interdisciplinary Mountain Research, Austrian Academy of Sciences
IGG	Institute for Geosciences and Geography, Physical Geography, Martin-Luther-University of Halle-Wittenberg, Germany
IGH	Institute of Geography, University of Hamburg
IGI	Institute of Geography, University of Innsbruck
IIE	Institute for Infrastructure Engineering, University of Salzburg
IMGI	Institute of Meteorology and Geophysics, University of Innsbruck
IPA	International Permafrost Association
IWHW	Inst. For Water Management, Hydrology and Hydraulic Engineering
L.I.F.E.	Laser induced fluorescence emission
LMD	Laboratoire de Météorologie Dynamique
NCAR	National Center for Atmospheric Research, Boulder, CO, USA
OEAV	Austrian Alpine Club
PROSA	Proglacial Systems of the Alps
SAINT	Snow cover Atmosphere Interactions
SAR	Synthetic aperture radar
TC	The Cryosphere
UBZ Graz	Umwelt-Bildungs-Zentrum Steiermark
US	University of Salzburg
VGK	Verein Gletscher Klima
WGMS	World Glacier Monitoring Service
WRF	Weather Research and Forecasting Model
ZAMG	Central Institute for Meteorology and Geodynamics

Elisabeth Schlosser



International Glaciological Society

JOURNAL OF GLACIOLOGY

Papers accepted for publication between 1 January and 30 April 2015. The papers are listed in alphabetical order by first author. Some of these papers have already been published.

Othmar Buser, Perry Bartelt

An energy-based method to calculate streamwise density variations in snow avalanches

P. Jay Fleisher

Lacuna band (surface depressions) occurrence and conditions of formation, Bering Glacier, Alaska

Gao Tanguang, Kang Shichang, Lan Cuo, Zhang Tingjun, Zhang Guoshuai, Zhang Yulan, Mika Sillanpää

Simulation and analysis of glacier runoff and mass balance in the Nam Co basin, southern Tibetan Plateau

Alexandra L. Giese, Robert L. Hawley

Reconstructing thermal properties of firn at Summit, Greenland, from a temperature profile time series

Wanqin Guo, Shiyin Liu, Junli Xu, Lizong Wu, Donghui Shangguan, Xiaojun Yao, Junfeng Wei, Weijia Bao, Pengchun Yu, Qiao Liu, Zongli Jiang

The second Chinese glacier inventory: data, methods and results

Jordan C. Hanson, Steven W. Barwick, Eric C. Berg, Dave Z. Besson, Thorin J. Duffin, Spencer R. Klein, Stuart A. Kleinfelder, Corey Reed, Mahshid Roumi, Thorsten Stezelberger, Joulieu Tatar, James A. Walker, Liang Zou

Radar absorption, basal reflection, thickness and polarization measurements from the Ross Ice Shelf

Sam Herreid, Francesca Pellicciotti, Alvaro Ayala, Anna Chesnokova, Christian Kienholz, Joseph Shea, Arun Shrestha

Satellite observations show no net change in the percentage of supraglacial debris-covered area in northern Pakistan from 1977 to 2014

Matthias Huss, Laurie Dhulst, Andreas Bauder

New long-term mass balance series for the Swiss Alps

Joseph H. Kennedy, Erin C. Pettit

The response of fabric variations to simple shear and migration recrystallization

Christian Kienholz, Sam Herreid, Justin L. Rich, Anthony A. Arendt, Regine Hock, Evan W. Burgess

Derivation and analysis of a complete modern-date glacier inventory for Alaska and northwest Canada

J. Kingslake

Chaotic dynamics of a glaciohydraulic model

R. Kwok, C. Haas

Effects of radar side-lobes on snow depth retrievals from Operation IceBridge

Poul-Henrik Larsen, Marc Overgaard Hansen, Jørgen Buus-Hinkler, Klaus Harnvig Krane, Carsten Sønderskov

Field tracking (GPS) of ten icebergs in Eastern Baffin Bay offshore Upernavik, northwest Greenland

Harold Lovell, Edward J. Fleming, Douglas I. Benn, Bryn Hubbard, Sven Lukas, Kathrin Naegeli

Former dynamic behaviour of a cold-based valley glacier on Svalbard revealed by basal ice and structural glaciology investigations

Douglas R. MacAyeal, Olga V. Sergienko, Alison F. Banwell

A model of viscoelastic ice-shelf flexure

M.H. Masiokas, S. Delgado, P. Pitte, E. Berthier, R. Villalba, P. Skvarca, L. Ruiz, J. Ukita, T. Yamanokuchi, T. Tadono, S. Marinsek, F. Couvreur, L. Zalazar

Inventory and recent changes of small glaciers on the northeast margin of the Southern Patagonia Icefield, Argentina

Elizabeth M. Morris, Duncan J. Wingham

Uncertainty in mass-balance trends derived from altimetry: a case study along the EGIG line, central Greenland

Anais J. Orsi, Kenji Kawamura, John M. Fegyveresi, Melissa Headly, Richard B. Alley, Jeff Severinghaus

Differentiating bubble-free layers from melt layers in ice cores using noble gases

Myrto Pirli, Kenichi Matsuoka, Johannes Schweitzer, Geir Moholdt

Seismic signals from large, tabular icebergs drifting along the Dronning Maud Land coast, Antarctica, and their significance for iceberg monitoring

D. Price, J. Beckers, R. Ricker, N. Kurtz, W. Rack, C. Haas, V. Helm, S. Hendricks, G. Leonard, P.J. Langhorne

Evaluation of CryoSat-2 derived sea-ice freeboard over fast ice in McMurdo Sound, Antarctica

Heidi Sevestre, Douglas I. Benn

Climatic and geometric controls on the global distribution of surge-type glaciers: implications for a unifying model of surging

Sharon B. Sneed, Paul A. Mayewski, W.G. Sayre, Michael J. Handley, Andrei V. Kurbatov, Kendrick C. Taylor, Pascal Bohleber, Dietmar Wagenbach, Tobias Erhardt, Nicole E. Spaulding

New LA-ICP-MS cryocell and calibration technique for sub-millimeter analysis of ice cores

Scott A. Snyder, Erland M. Schulson, Carl E. Renshaw

The role of damage and recrystallization in the elastic properties of columnar ice

Shin Sugiyama, Daiki Sakakibara, Shun Tsutaki, Mihiro Maruyama, Takanobu Sawagaki

Glacier dynamics near the calving front of Bowdoin Glacier, northwestern Greenland

Victor C. Tsai, Andrew L. Stewart, Andrew F. Thompson

Marine ice-sheet profiles and stability under Coulomb basal conditions

C. Vincent, E. Thibert, O. Gagliardini, A. Legchenko, A. Gilbert, S. Garambois, T. Condom, J.M. Baltassat, J.F. Girard

Mechanisms of subglacial cavity filling in Tête Rousse glacier

Denis Voytenko, Alon Stern, David M. Holland, Timothy H. Dixon, Knut Christianson, Ryan T. Walker

Tidally driven ice speed variation at Helheim Glacier, Greenland, observed with terrestrial radar interferometry

L.M. Wake, S.J. Marshall

Assessment of current methods of positive degree-day calculation using in situ observations from glaciated regions

Alexandra Waechter, Luke Copland, Emilie Herdes

Modern glacier velocities across the Icefield Ranges, St Elias Mountains, and variability at selected glaciers from 1959 to 2012

Meilin Zhu, Tandong Yao, Wei Yang, Fabien Maussion, Eva Huintjes, Shenghai Li

Comparison of energy and mass balance between Zhadang and Parlung No.4 Glaciers on the Tibetan Plateau

ANNALS OF GLACIOLOGY 56(69)

The following papers have been selected for publication in Annals of Glaciology 56(69) (thematic issue on Sea ice in a changing environment), edited by Petra Heil

Agneta Fransson, Melissa Chierici, Katarina Abrahamsson, Maria Andersson, Anna Granfors, Katarina Gårdfeldt, Anders Torstensson, Angela Wulff
CO₂-system development in young sea ice and CO₂ gas exchange at ice/air interface mediated by brine and frost flowers in Kongsfjorden, Spitsbergen

Cathleen A. Geiger, Hans-Reinhard Müller, Jesse Samluk, E. Rachel Bernstein, Jacqueline A. Richter-Menge
Impact of spatial aliasing on sea-ice thickness measurements

Cathleen A. Geiger, Peter Wadhams, Hans-Reinhard Müller, Jacqueline A. Richter-Menge, Jesse Samluk, Tracy L. Deliberty, Victoria Corradina
On the uncertainty of sea-ice isostasy

Masato Ito, Kay I. Ohshima, Yasushi Fukamachi, Daisuke Simizu, Katsushi Iwamoto, Yoshimasa Matsumura, Andrew R. Mahoney, Hajo Eicken
Observations of supercooled water and frazil ice formation in an Arctic coastal polynya from moorings and satellite imagery

Alison Kohout, Bill Penrose, Scott Penrose, Michael Williams
A device for measuring wave-induced motion of ice floes in the Antarctic marginal ice zone

Kazuya Kusahara, Tatsuru Sato, Akira Oka, Takashi Obase, Ralf Greve, Ayako Abeouchi, Hiroyasu Hasumi
Modelling the Antarctic marine cryosphere at the Last Glacial Maximum

J.V. Lukovich, J.K. Hutchings, D.G. Barber
On sea-ice dynamical regimes in the Arctic

Sarah M. Mager, Gregory H. Leonard, Andrew G. Pauling, Inga J. Smith
A framework for estimating anchor ice extent at potential formation sites in McMurdo Sound, Antarctica

Andrew R. Mahoney, Hajo Eicken, Yasushi Fukamachi, Kay I. Ohshima, Daisuke Simizu, Chandra Kambhamettu, M.V. Rohith, Stefan Hendricks, Joshua Jones
Taking a look at both sides of the ice: comparison of ice thickness and drift speed as observed from moored, airborne and shore-based instruments near Barrow, Alaska

Yoshimasa Matsumura, Kay I. Ohshima
Lagrangian modelling of frazil ice in the ocean

Walter N. Meier, Florence Fetterer, J. Scott Stewart, Sean Helfrich
How do sea ice concentrations from operational data compare with passive microwave estimates?: Implications for improved model evaluations and forecasting

Ioanna Merkouriadi, Matti Leppäranta
Influence of sea ice on the seasonal variability of hydrography and heat content in Tvärminne, Gulf of Finland

Fabien Montiel, Vernon A. Squire, Luke G. Bennetts
Reflection and transmission of ocean wave spectra by a band of randomly distributed ice floes

Jesse P. Samluk, Cathleen A. Geiger, Chester Weiss, James Kolodzey
Full-physics 3-D heterogeneous simulations of electromagnetic induction fields on level and deformed sea ice

Lars H. Smedsrud, Torge Martin
Grease ice in basin-scale sea-ice ocean models

More papers for Annals 56(69) will be listed in the next issue

ANNALS OF GLACIOLOGY 56(70)

The following papers have been selected for publication in Annals of Glaciology 56(70) (thematic issue on Contribution of glaciers and ice sheets to sea level change), edited by Richard Hindmarsh and Frank Pattyn

Lionel Benoit, Amaury Dehecq, Ha-Thai Pham, Flavien Vernier, Emmanuel Trouvé, Luc Moreau, Olivier Martin, Christian Thom, Marc Pierrot-Deseilligny, Pierre Briole
Multi-method monitoring of Glacier d'Argentières glacier dynamics

William Colgan, Jason E. Box, Morten L. Andersen, Xavier Fettweis, Beáta Csathó, Robert S. Fausto, Dirk van As, John Wahr
Greenland high-elevation mass balance: inference and implication of reference period (1961–90) imbalance

Victoria Lee, Stephen L. Cornford, Antony J. Payne
Initialization of an ice-sheet model for present-day Greenland

Stefan R.M. Ligtenberg, Brooke Medley, Michiel R. van den Broeke, Peter Kuipers Munneke
Antarctic firn compaction rates from repeat-track airborne radar data. Part 2: firn model evaluation

Sebastian Marinsek, Evgeniy Ermolin
Ten year mass balance by glaciological and geodetic methods of Glaciario Bahía del Diablo, Vega Island, Antarctic Peninsula

Brooke Medley, Stefan R.M. Ligtenberg, Ian R. Joughin, Michiel R. van den Broeke, Sivaprasad Gogineni, Sophie Nowicki
Antarctic firn compaction rates from repeat-track airborne radar data. Part 1: methods

Alvaro Soruco, Christian Vincent, Antoine Rabatel, Bernard Francou, Emmanuel Thibert, Jean Emmanuel Sicart, Thomas Condom
Contribution of glacier runoff to water resources of La Paz city, Bolivia (16°S)

Andrew Zammit-Mangion, Jonathan L. Bamber, Nana Schoen, Jonathan C. Rougier
A data-driven approach for assessing ice-sheet mass balance in space and time

More papers for Annals 56(70) will be listed in the next issue

ANNALS OF GLACIOLOGY 57(71)

The following papers have been selected for publication in Annals of Glaciology 57(71) (thematic issue on Glaciology in High Mountain Asia), edited by Graham Cogley

J. Graham Cogley
Glacier shrinkage across high-mountain Asia

Lucas Earl, Alex S. Gardner
A satellite-derived glacier inventory for North Asia

Wenfeng Huang, Runling Li, Hongwei Han, Fujun Niu, Qingbai Wu, Wenke Wang
Ice processes and surface ablation in a shallow thermokarst lake in the Central Qinghai-Tibet Plateau

Azamat Kaldybayev, Yaning Chen, Evgeniy Vilesov
Glacier change in the Karatal River Basin, Zhetysay (Dzhungar) Alatau, Kazakhstan

Marlene Kronenberg, Martina Barandun, Martin Hoelzle, Matthias Huss, Daniel Farinotti, Erlan Azisov, Ryskul Usubaliev, Arbor Gafurov, Dmitry Petrakov, Andreas Käb
Mass-balance reconstruction for Glacier No. 354, Tien Shan, from 2003 to 2014

Evan S. Miles, Francesca Pellicciotti, Ian C. Willis, Jakob F. Steiner, Pascal Buri, Neil S. Arnold
Refined energy-balance modelling of a supraglacial pond, Langtang Khola, Nepal

Aparna Shukla, Iram Ali
A hierarchical knowledge-based classification for glacier terrain mapping: a case study from Kolahoi Glacier, Kashmir Himalaya

More papers for Annals 57(71) will be listed in the next issue



Nordic Branch Meeting 2014

Mýrdalur, Iceland, 30 October–1 November 2014

Of the five hosting countries of the IGS Nordic branch (Denmark, Finland, Iceland, Norway and Sweden), Iceland is the most eagerly awaited host, as much for the thrilling glacio-volcanic research as for the radical changes of scenery and weather.

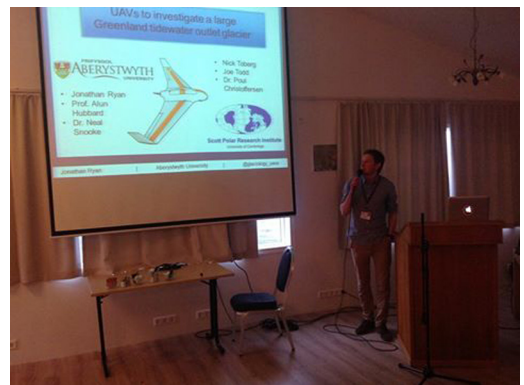
On Thursday 30 October, approximately 85 participants gathered in front of Askja, the Natural Science building of the Háskóli Íslands (University of Iceland). A large number had already met during the previous few days at the well-attended beginner Elmer course held at the Icelandic Met Office and the annual meeting of SVALI, a Nordic Centre of Excellence that involves nearly all Fenno-scandinavian glaciological research groups. The crowd was on the cheerful side, although the weather was mild and rainy and the wind was chilly. Two buses and a few rental cars left in the morning for the 2½-hour journey to Vík, a village south of Mýrdalsjökull. Once out of Reykjavík, we quickly reached the lava fields, nicely blanketed with snow and punctuated with vents emitting steam and other gases. An hour later, we were within sight of Eyjafjallajökull, along the flanks of which waterfalls were pouring down. At this point, the weather deteriorated 'slightly'. Water was going in all directions, flowing up as easily as it was falling. Driving became a dance, swinging from British-side driving to continental-side driving. Arrival and unloading at Hotel Dyrhólaey was accomplished at great speed.

The Icelandic breeze brought every one back to life and eventually inside, except for a few who enjoyed horizontal rain and gliding off higher terrain. It suddenly made sense that Icelandic houses looked sober from the outside. Inside, the welcoming committee was animated and happily badging the participants, who in settled for the 3-day conference.

Under the auspices of Katla, Magnús Magnússon and the local organizers (Alexander Jarosch and Eyjólfur Magnússon), the meeting was officially opened. The first session offered a refreshing overview of the state and fate of glaciers from Svalbard to mainland Norway, passing by Sweden, Greenland and Iceland. May glaciologists become an endangered species. Nevertheless, glaciers and ice are still causing trouble and the audience was reminded of cryosphere-related accidents. As Jack Kohler summarized it, 'Ice Kills' – not only humans, but also Svalbard reindeer. This session must have been cursed, as the meeting mysteriously lost one of its speakers, Andy Russell. We were still within the 5% acceptable loss rate and the meeting continued with Jonathan Ryan presenting an impressive UAV show for extracting elevation changes at glacier termini in Greenland. Outside the meeting hall, UAVs would not have lasted very long. Windows bulged with each turbulent gust. The poster session included 33 posters and took place in the



Jack Kohler's talk on 'Extreme icing events in snowpack in High Arctic site' started with a very drastic slide. The following slide had the title 'Ice gives life' to give us all some hope..



The first talk given by a student was Jonathan Ryan's presentation on 'Using UAVs to investigate a tidewater glacier in Greenland', amassing the innovative uses people find for what is a relatively new technology.



A short, refreshing break outside the Hotel Dyrhólaey and conference hall.

protected corridors of the hotel. Iceland was well represented, with nine posters discussing mass balance, tefra effect on albedo, palaeo-reconstruction and glacial isostatic adjustment. Discussing the exciting developments at Bárðarbunga caldera, Bergur Einarsson noted that this summer's eruption strangely has not caused any jökulhlaup. No increase in discharge was seen in the neighbouring catchments, although depressions formed at the glacier surface, possibly indicating subglacial drainage. It may be the start of a quest for the missing water of Bárðarbunga. The session also had several posters about the glaciers in Kongsfjorden, Svalbard, with a particular focus on the ice dynamics of Kronebreen (Penelope How, Silje Smith-Johnsen and Dorothée Vallot) as well as firn and precipitation patterns in the accumulation zone (Ward van Pelt and Ankit Pramanik). Other works focused on snow accumulation from GPR study, palaeo-reconstruction (Henry Patton), fast full-Stokes modelling of the Barents Sea ice sheet (James Lea), and building an extensive mass-balance database for the Greenland ice sheet (Horst Machguth). The poster session was informal and busy with presenting and discussing from start to finish and beyond. As the horses in the field huddled together for shelter, we eventually gathered and enjoyed a light dinner. The night was short for many. The wind didn't give the participants any let-up. The peak of the storm hit Hotel Dyrhólaey early in the morning and reached a maximum speed of 43 m s^{-1} . You were well-advised to hold the door and brace yourself when passing from one building to another.

The morning session offered insights on many aspects of modelling glacier components to obtain runoff, glacier geometry, velocity and damage. The audience particularly appreciated the statistical modelling of snow runoff from masters student Ingunn Weltzien. The Friday afternoon was also rich in quality and ended with the best student



The winners of the IGS Nordic Branch Ýmir student award 2014. Best poster award went to Pierre-Marie Lefeuve (better known as PiM). Because of the very stiff competition the IGSNB awards committee decided to give the best oral presentation award jointly to two students, Hrafnhildur Hannesdóttir and Vikram Goel. Here are the winners and the committee. Left to right: Olivier Gagliardini, PiM, Vikram, Hrafnhildur, Guðfinna Aðalgeirsdóttir (better known as Tollý) and Liss Marie Andreassen.

presentations (later awarded). Exceptionally this year, they were awarded to two PhD students: Hrafnhildur Hannesdóttir, for her study on orographic precipitation in southeast Vatnajökull, Iceland, and Vikram Goel, for his work on ice rises in Dronning Maud Land, Antarctica. The last presentation of the day was most inspiring and discussed opportunities for outreach activities, such as those Andreas Ahlstrøm and Signe Hillerup have created with isskolen.dk (http://isskolen.dk/wp/?page_id=7477). A message to take home: Outreach is a crucial job for any glaciologist – it conveys interest in our field to future generations, and funding agencies value more and more such output from projects. In the same spirit and as an invited presentation, geophysicist Magnús Tumi Guðmundsson gave the participants an update on the latest eruption at Bárðarbunga. Although it has received much less press coverage than the last eruption of Eyjafjallajökull, the volume of lava produced is the largest ($<2 \text{ km}^3$) since the Laki eruption of 1783 (14.7 km^3), which is famous for causing famine in Europe and ultimately the French revolution. The dataset being currently collected at the surface of Bárðarbunga, including GPS located in the currently collapsing caldera, is remarkable and noteworthy. This was the last presentation of a long day of scientific discussion, which continued during the banquet and spilled into the night at the hotel bar.



Andy Russell (Newcastle University) presenting geomorphological evidence of the jökulhlaup events at Gígjökull following the last volcanic eruption below Eyjafjallajökull. Photo: Solveig Havstad Winsvold.

The last day of the conference felt short and focused. First on glacier surface processes: Sergey Marchenko presented the problems in extrapolating cores to infer surface stratigraphy; Charalampos Charalampidis showed the significant effect of water retention in increasing snowpack temperature in Greenland's accumulation zone. The final session on geodetic mass balance was original in terms both of research and entertainment. Joaquin Belart and Johan Nilsson offered insightful talks

on retrieving DEMs from combining historical airborne images with LiDAR and on improving CryoSat-2 elevation accuracy, respectively. The two last talks from Kirsty Langley and Geir Moholdt invited the audience to a glacier quiz and kept us all alert until the end of the meeting and the start of the weekend excursions.

After some clarification about payments for the trips, which were confusing for both participants and organizers, the buses headed to Gígjökull, located on the north face of Eyjafjallajökull. The drive took longer than expected, especially the last 15 km. The bus was of the same type as a city bus and had to be carefully and slowly coaxed across rivers and eroded banks. Nonetheless, Tómas Johannesson, our enthusiastic guide, entertained the passengers by explaining how the outwash plain was remodelled during the 2009 eruption after two jökulhlaups. This valley in its autumn colours was particularly dramatic, and is famous in the Icelandic sagas. Tómas explained that, in *Njáls Saga*, Gunnar Hámundarson, a virtuous warrior forced into exile after a clan war, looked back as he left the valley, was struck by the beauty of the landscape and resolved to stay on his land even though he knew it meant certain death. This produced the most beautiful poem in all the sagas, according to our guide, who recited the original version. The bus finally had to stop by a river 1 km before our destination. We hiked from there up the impressive moraine for an overview of the remaining bits of Gígjökull. The glacier suffered severely during the eruption and jökulhlaups, which eroded a deep canyon into its west-side. After scrambling down to the glacier front and the canyon, we caught up with the bus and had one last stop, at the Eyjafjallajökull Visitor Centre, before heading to our hotel.

The landscape that prevented the exile of the warrior Gunnar Hámundarson in *Njáls Saga*. He could not bring himself to leave such a beautiful place. Photo: Solveig Havstad Winsvold.





Panoramic view of Gígjökull from the heights of the lateral moraine. Photo: Ingunn Weltzien.

The next day, plans were changed to accommodate the weather. The organizers had contacted a local guide, whose family once lived on an isolated rocky outcrop sticking out of the outwash plain of Mýrdalsjökull. This island, although connected to road N1, looks like a stranded iceberg surrounded by a sea of black sand, with wave-like dunes. Battered by wind and rain, our guide led us to the top, where the tomb of his ancestors lies. When the island was still inhabited, the residents preferred the relatively quieter southern side. The southern cliffs offered a spectacular view of the island and the sand dunes. Several ventured right to the cliff edge for an unforgettable picture, despite the warnings of our colleague Ágúst Þór Gunnlaugsson, Icelandic masters student, who is a member of the national

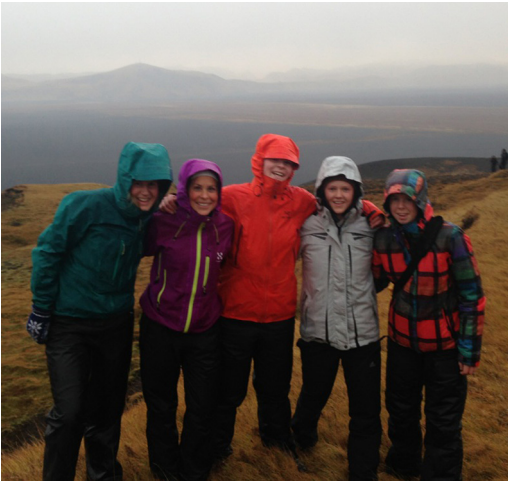
rescue team. We were no different from the tourists. This was also demonstrated at our next stop, at Sólheimajökull, which the group seemed to enjoy. Sólheimajökull is an outlet glacier of Mýrdalsjökull, studied by the Universities of Iceland and Edinburgh, and is one of the glaciers monitored by the Extreme Ice Survey (<http://extremeicesurvey.org/>). The retreat of the glacier has led to the formation of a proglacial lake and forced the guiding companies to search for new access points a kilometre upstream from where they used to walk on the ice. Back on the bus,



Lunch break inside a former volcanic cavity. Photo: Solveig Havstad Winsvold.



From the proglacial lagoon to the ash mounds and fractured surface of Sólheimajökull. Photo: Solveig Havstad Winsvold.



Masters students enjoying the weather. Photo: Ingunn Weltzien.

we stopped at Skógafoss, a large waterfall flowing down from the upper plateau. After such an arduous trip, the local organizers had the great idea of taking us to an Icelandic pool in Selfoss. After being warned that in Iceland pools are not about swimming, but about relaxing, the 40 participants stormed into the small local bath. This was definitely the highlight of the trip and it felt so good to finish our Icelandic journey bathing in a heitur pottur (hot pot)!

Pierre-Marie (PiM) Lefevre



Walking back from the margins of Sólheimajökull. Photo: Ingunn Weltzien.



Intense discussion at the top of the waterfall Skógafoss. Photo: Ingunn Weltzien.

Obituary: Charles Swithinbank, 1926–2014

Charles Winthrop Molesworth Swithinbank, a distinguished polar glaciologist, died on 27 May 2014 aged 87. His career, exceeding six decades, covered the major period of the development of his science and its many practical applications. In total he spent three winters, more than 20 field seasons, in both polar regions, and made many briefer visits.

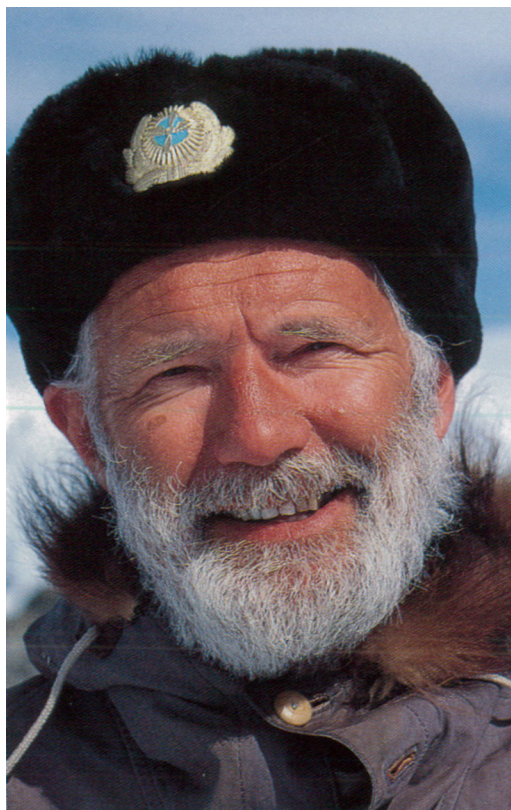
He was born in Burma on 17 November 1926; an autobiographical work explained why 'a fairly normal young man should find such an abnormal occupation [as a glaciologist]', noting his mother's advice, 'Don't get stuck in an office like your father.' In his 80th year Charles returned to Burma, now Myanmar, for a holiday, making an extensive tour during which he revisited places he remembered from childhood.

His education began in Britain at the age of 7 during which he began boarding at Bryanston School, Dorset, on the same date as, 5 years later, the Second World War began. Towards the end of the war he enlisted in the Royal Navy, coincidentally in the same week as D-Day. He served 2½ years in the navy during which he visited Spitsbergen where the Arctic landscape left a lasting impression.

In 1946 he entered Pembroke College, Oxford, where he read geography. In the next year he was a member of the Oxford University Exploration Club expedition to Vatnajökull, Iceland, man-hauling. His autobiography then notes he was asked if he wanted to go to Antarctica and, as he wrote, 'it took me a fraction of a second to reply. In that second the course of my life was changed forever.'

Thus, after training in Swedish Lapland, he became a member of the Norwegian–British–Swedish Antarctic Expedition of 1949–1952. During two winters and three summers, based at Maudheim, Dronning Maud Land, he was surveying glaciological features which included making pioneer studies of the thickness of the Antarctic ice sheet.

In 1952 he was back in Oxford completing his Antarctic results for a doctorate awarded in 1955. In the next year his research concerned the distribution of pack ice in the Northwest Passage for the Defence Research Board of Canada. While in North America he met Vilhjalmur Stefansson, who introduced him to his specialist polar library. There he met Mary Fellows, who became his wife in 1960.



Following this, Charles moved to Cambridge and the Scott Polar Research Institute (SPRI). At this meeting place for polar specialists Charles described how after a 'pub crawl' he met a colleague and, by fortunate coincidence, this resulted in a 30 year association with US polar and glaciological research. This began in the University of Michigan, investigating the dynamics of the Ross Ice Shelf. Thus, in 1960, he was back in the Antarctic at the time when international cooperation under the Antarctic Treaty was beginning. His work involved extensive field travelling, during which he visited Roald Amundsen's 1912 cairn on Mount Betty.

In 1963, after three Antarctic seasons, he moved back to Cambridge with a research appointment with SPRI, an association that continued for the rest of his life. By arrangement with SPRI, the Royal Society and the British

Antarctic Survey (BAS), from 1963–1965, under the provisions of the Antarctic Treaty, Charles was the British exchange scientist with the Soviet Antarctic Expeditions. He wintered with them at Novolazarevskaya station, again studying glacial movements. While there he learnt Russian as a fourth language.

On his return to Cambridge he worked with the radio-echosounding programme of SPRI surveying the depths of the Antarctic ice sheet by 'radio-glaciology'. In 1967 he worked from the BAS base 'Adelaide' with a series of flights measuring the ice depth to bedrock, the beginning of a programme that eventually covered the entire continent, with much international cooperation. In the next summer this continued from McMurdo station, cooperating with the US Antarctic Research Program.

Back to the Northwest Passage, in 1969 Charles was an observer during the voyage of *Manhattan*, an ice-strengthened oil tanker, experimentally assessing the practicability of its use for the transport of crude oil. The logistic and economic aspects were such that the Alaska pipeline turned out to be a more practicable method.

Sea-ice observations continued in 1971, but from below. Charles was aboard HMS *Dreadnought*, a nuclear powered submarine of the Royal Navy that, incidentally, was the first British submarine to reach the North Pole. The voyage was the beginning of a long period of naval cooperation for SPRI. On 3 March 1971 the submarine surfaced and Charles stood at the North Pole. Later that summer he was again in the Arctic, involved with experimental airborne radio-echo surveys over Greenland, Ellesmere Island and the Arctic Ocean. The base for these flights was the USA's station in Thule.

During the 1971/72 austral summer Charles was again involved with radio-echo traverses working from the Adelaide Island base of BAS. Results from these surveys gave early indications of the substantial depletion of several major ice shelves.

In 1974 Charles was appointed as the head of the Earth Sciences Division of the BAS, which was based at SPRI until 1976, when all divisions of BAS consolidated in a new headquarters just outside Cambridge. Charles held this post, responsible for Antarctic glaciology, geophysics and geology, until he retired in 1986.

In early 1975, while flying near the Ellsworth Mountains on radio-echo surveys, Charles noticed large areas of snow-free ice, which suggested possibilities of landing wheeled aircraft. At this time, as a division head of a government scientific body, he also noted the increase in

his administrative duties but made a point of continuing research. In 1978/79 he was back in McMurdo remeasuring the Byrd Glacier and comparing results from those obtained 11 years previously.

In 1982, suddenly and unexpectedly, Charles became involved with the Argentinian invasions of South Georgia and the Falkland Islands by providing specialist advice to the British government. One of the consequences was an appreciation, by government, of the importance to the country of the Antarctic regions, with the result of an approximate doubling of funds for British Antarctic research.

Among Charles's continuing projects were reconnaissance surveys from satellite imagery and its application to glaciological research. This provided major contributions to series of Antarctic charts. In 1988 he completed a Satellite Image Atlas of Glaciers of the World, published by the United States Geological Survey, a culmination of observations from decades of satellite imagery.

During 1983, liaison between the Chilean Air Force and BAS developed, including the possibility of wheeled landings on inland ice. Radio-echo surveys also continued, much in cooperation with the USA, which provided large aircraft-deploying depots for the smaller, more versatile, British Twin Otter aircraft. In 1985/86 Charles spent his last field season with BAS. He retired in November 1986.

A combination of extra time available after retirement, knowledge of bare ice areas, liaison with the Chilean Air Force, and several other interested parties led to a major project. This was the investigation of the practicability of landing wheeled aircraft on the snow-free ice of the Antarctic interior. The result was the beginning of summer flights from Punta Arenas to a base camp at Patriot Hills, high on the ice sheet, which began in 1988. They were able to extend flights, using ski-equipped aircraft, to the South Pole, the vicinity of Mount Vinson and elsewhere. This began to open the Antarctic interior to mountaineers, skiers, other sportsmen, tourists and various non-governmental visitors. Once their practicability was proven, inter- and intracontinental flights began as a part of several national programmes, often in cooperation.

Charles always travelled widely beyond the polar regions, lecturing at international meetings, universities and other specialized organizations. His subjects ranged as widely as living on Mars, experience gathered on Antarctic stations being relevant to living on planetary bases. He was also an accomplished lecturer on passenger voyages to many Arctic regions, including the North Pole, and to the Antarctic, where he also made several

visits to the South Pole. Privately, many of his excursions were to other glaciated parts of the world, including much of Russia, the Himalaya and Tibet.

Charles wrote four autobiographical books: *An Alien in Antarctica: Reflections upon Forty Years of Exploration and Research on the Frozen Continent* (1997), *Forty Years on Ice: A lifetime of Exploration and Research in the Polar Regions* (1998), *Foothold on Antarctica: The First International Expedition (1949–1952)* (1999), and *Vodka on Ice: A Year with the Russians in Antarctica* (2002). Each of these is well illustrated from his extensive catalogued collection of photographic material (now bequeathed to SPRI). In 2010, he was interviewed for the Oral History of British Science project of the British Library, providing 83 minutes of detailed reminiscences. The SPRI library records 135 of his publications, and its archives and museum have also been enhanced by material he has donated. Academically and socially SPRI also benefited from his advice and guidance to many students, visiting scholars, numerous other visitors, and members of staff.

Such an active life led to membership of many organizations dealing with polar and associated subjects, often as a committee member and occasionally as President. These include the American Geographical Society, Antarctic Club (President 1998), Antarctic Heritage Trust (UK), Arctic Club (President 2007), Arctic Association of North America, British Antarctic Survey Club,

Falkland Islands Association, Friends of Scott Polar Research Institute, Geographical Club, International Commission on Snow and Ice, International Glaciological Society (President 1963–66 and 1981–84), James Caird Society, Old Antarctic Explorers Association, Royal Geographical Society, South Georgia Association (President 2007–12) and Trans-Antarctic Association.

Charles Swithinbank's awards include the Norwegian Medal of Merit (1952) the Polar Medal (1956), the Retzius Medal of Sweden (1966), the Patron's Medal of the Royal Geographical Society (1971) and the Mungo Park Medal of the Royal Scottish Geographical Society (1990). In 2013 he was decorated with the MBE. His name is commemorated by six toponyms in Australian, British, New Zealand and Norwegian regions of Antarctica (four being 'Swithinbank' features and two for 'Charles').

He married, in 1960, Mary Fellows (née Stewart), with whom he had a daughter and a son, and adopted her daughter from a previous marriage.

At the conclusion of his autobiography *Forty Years on Ice* he wrote: 'I have heard it said that today, with easier access to high latitudes, the challenge has gone out of polar fieldwork. Those who believe it should stay at home – to avoid being disillusioned.'

Bob Headland

Obituary: Robert H. Thomas, 1937–2015

Robert H. (Bob) Thomas was born 1 June 1937 in Hoylake, UK. He died on 2 February 2015 in Gorzow, Poland, from the effects of a stroke that he suffered in early January. He was 77. Bob is survived by his wife, Dr Roma Thomas, MD, five children (Conrad and Emma with Roma Thomas, James and Clare from a previous marriage with Ursula Chojnacka, and a daughter Kate from his first marriage with Pamela); and four grandchildren (Emmanuelle, Charlotte, Zachary and Jasper).

Bob's interest in glaciology began during a 2 year Antarctic deployment (1960–1961) as a meteorological observer at Faraday Station, on Galindez Island, where he found himself intrigued by the flow of nearby ice caps. Spending his free time learning to survey stake networks with optical surveying equipment, he developed a deep respect for the power of observation in interpreting the moving glacier ice all around him. Later in life he would say, 'My driving principle was to measure everything I could about ice.'

Following his deployment to Faraday Station, and after traveling for a time through South America, Bob returned to the UK intent on becoming a professional glaciologist. He returned to Antarctica in 1966/67 as a field assistant with the British Antarctic Survey (BAS) team at Halley Bay Station. Sir Vivian Fuchs ran BAS at the time, and those assigned to the station, which they found buried under 10 m of snow on the edge of the Brunt Ice Shelf, still possessed the British spirit of exploration.

At Halley Bay, Bob was true to his driving principle and 'measured the hell out of the Brunt Ice Shelf and its adjoining bit of ice sheet'. As he gathered more data from his stake networks and strain rosettes, he began to notice that the strain rates along a flow line leading from the inland ice sheet and across the grounding line to the calving front of the ice shelf were strongly influenced by a patch of grounded ice shelf called the McDonald Ice Rumples (then called the Gin Bottle). Bob boldly drew a connection between the ice rumples, the flow of the ice shelf and flow across the grounding line. Bob explained this connection years later:

Afterwards [after returning from Halley Bay], back in Cambridge, I was able to use all these measurements to show how important the Gin Bottle was to the existence of the Brunt Ice Shelf,



and this discovery has since been the foundation stone upon which I have built a hypothesis describing the stability of the Antarctic ice sheet under attack from climate warming. In this scenario, the ice shelves are the dams that prevent accelerated discharge of much of the ice sheet into the ocean. Weakening of the peripheral ice shelves would open a door to greatly accelerated discharge of much of the inland ice sheet into the ocean, resulting in sea-level rise.

Bob's work with the Brunt Ice Shelf data, which he acquired using optical survey instruments, tape measures and dog sleds, led him to publish his theory of ice-shelf buttressing of the inland ice sheet feeding the shelves.

The concept of ice-shelf buttressing, that the forward flow of inland ice across grounding lines is resisted by the floating ice shelves seaward of grounding lines, because of their confinement in embayments whose margins provide shear resistance, with additional resistance provided by high points on the sea floor that intersect the bottom surfaces of the floating shelves forming ice rises, became a major theme of his life's

work. It is writ large today; Bob's phrase 'ice-shelf buttressing' is the subtitle of a section of the 2013 Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5).

Armed with his data from the Brunt Ice Shelf, Bob began work on a PhD at the Scott Polar Research Institute (SPRI) in Cambridge, England. There he was exposed to the local luminaries of UK glaciology – his thesis was mentored by Charles W.M. Swinbank (1926–2014) and Gordon deQ. Robin (1927–2004) – and, in addition, to prominent visitors well known for advancing glaciological research. They included Johannes Weertman (of Northwestern University, USA), who had formulated the first quantitative description of ice-shelf flow and was working on his soon-to-be-published paper showing that a marine ice sheet such as that of West Antarctica is not necessarily stable, and William F. (Bill) Budd (of the University of Melbourne, Australia), who – in addition to his many contributions to the physics of ice deformation and flow – was an early developer of computational ice sheet modeling.

Bob completed and defended his PhD dissertation, entitled 'The dynamics of the Brunt Ice Shelf, Coates Land, Antarctica', in 1972. It was published as British Antarctic Survey Scientific Report No. 79 in 1973.

Bob expressed an iconoclastic view of Antarctic field work: it was that, in the wake of the International Geophysical Year (IGY, 1 July 1957–31 December 1958), much of what was going on in Antarctica was simply mapping 'what was there'. He believed early in his career that field work should be strategic, designed to answer scientific questions beyond simply making maps. One of his ideas was to follow-up on how ice shelves influence the flow of ice streams – ice sheet analogies to ocean currents – across their grounding lines. The great ice streams of the Marie Byrd Land sector of the West Antarctic ice sheet that discharged into the Ross Ice Shelf had then been discovered through an airborne radar-survey program carried out, in part, by his mentors and colleagues at SPRI.

Bob's progressive views of what an observational program in glaciology could deliver were noticed by the scientists who were organizing what would become the most ambitious field survey to date of a large component of the Antarctic Ice Sheet: the Ross Ice Shelf. In 1973 he was hired by the Ross Ice Shelf Project (RISP) Office, with support from H. Jay Zwally, then program manager for Antarctic and Arctic glaciology in the US National Science Foundation (NSF) Office of Polar Programs.

Bob teamed with Charles R. Bentley (of the University of Wisconsin Madison), a pioneer of



Bob Thomas surveying Jakobshavn Isbræ, West Greenland, 1976

Antarctic geophysics, to form a subproject called the Ross Ice Shelf Geophysical and Glaciological Survey (RIGGS). Earlier, Charles and Ned A. Ostenson had discovered – from analysis of the extensive seismic data they acquired during a series of long traverses across the inland West Antarctic ice sheet (WAIS) during 1957–60 – that WAIS is a marine ice sheet grounded far below sea level.

Bob, Charles Bentley and their graduate students planned and carried out a full and systematic survey of the glaciology and geophysics of the ~487 000 km² Ross Ice Shelf, including ice-shelf thicknesses, gravity anomalies, strain rosettes from which principal strain rates and flow velocities were subsequently derived, surface accumulation rates, and 10 m temperatures on a 50 km grid. They used De Havilland Twin Otter aircraft support and fly-in camps to accomplish the survey during 1973–78.

While working with Charles Bentley on RIGGS, Bob moved, at the invitation of glaciologist Terence J. Hughes (of the University of Maine), from the University of Nebraska, which was hosting the Ross Ice Shelf Project, to the Institute for Quaternary Studies at the University of Maine. There he joined Terence, glacial geologist George H. Denton and mathematician/numerical analyst David H. Schilling (on sabbatical from the University of Wisconsin-Barron County) who, in addition to working on problems of present ice flow in Antarctica and Greenland, were also participating in the multi-university NSF-funded Climate: Long Range Investigation, Mapping, and Prediction (CLIMAP) project. Douglas R. MacAyeal (whose BS in physics was from Brown University) joined Bob as an MS graduate student in physics, carried out field work with him on the Ross Ice Shelf and developed the first comprehensive finite element model of a large component of

the Antarctic ice sheet, the Ross Ice Shelf. Craig S. Lingle (whose BS in electrical engineering was from the University of Washington) joined Terence as an MS graduate student in geological sciences, worked on the CLIMAP ice sheet reconstruction, then subsequently worked with Terence, Bob and Ronald Kollmeyer (of the US Coast Guard) on a Coast Guard-supported survey of the floating, iceberg-calving Jakobshavns in West Greenland.

Over a period of about 5 years, Bob's interaction with the University of Maine group resulted in some of the best forward thinking that guides ice sheet glaciology to this day. His disciplined observations and thinking about the Brunt and Ross ice shelves culminated, in the late 1970s and early 1980s, in a prolific series of papers on marine ice sheet instability, ice-stream grounding-line dynamics and the controlling roles of the ice shelves. These included a 1979 paper published in *Nature* in which, with Timothy J.O. Sanderson (then of the British Antarctic Survey) and Keith E. Rose (then of SPRI), Bob suggested, based on his time-dependent ice-stream grounding-line model (developed in collaboration with David Schilling), that substantial degradation and thinning of the Ross Ice Shelf could result in disintegration of WAIS in a few centuries, resulting in a mean sea-level rise of 5 m.

In this, Bob was among a handful of visionary glaciologists who responded to the proposition first put forward by John H. Mercer (1922–87) in 1968, then in a paper published in *Nature* in 1978, that irreversible retreat of the West Antarctic ice sheet could be initiated by greenhouse warming of the Earth's climate.

Bob's ventures into theoretical ice-sheet glaciology must have been satisfying, but he always maintained a conviction that field observations were critical for progress in understanding how ice sheet stability and sea-level rise would be linked to future climate changes.

In 1980 Bob joined the glaciologists of the Oceans and Ice Branch of the Laboratory for Hydrospheric Processes at NASA Goddard Space Flight Center in Greenbelt, Maryland, where H. Jay Zwally – following work with the data from prototype radar altimeter satellites – recognized the potential of the radar altimetry acquired, during the (unfortunately-abbreviated) 100 day Seasat mission in 1978, for ice sheet mapping and as a baseline for future altimetry measurements of ice sheet elevation changes. Robert A. Bindschadler was also working in the Oceans and Ice Branch. There, Bob developed a new method for using satellite radar altimetry to map the margins of floating Antarctic ice shelves.

During this period, the extensive earlier measurements of the Thomas–Bentley team during

the Ross Ice Shelf Project motivated initiation of the first field research on the ice streams discharging from the inland West Antarctic ice sheet into the Ross Ice Shelf, about which little was then known. While at NASA/GSFC, Bob developed a successful proposal to NSF for a broad-scale study of the great ice streams of the Siple Coast.

In 1983, however, W. Stanley (Stan) Wilson, then manager of the NASA oceans program, offered Bob a position at NASA Headquarters managing the polar oceans component of his program. Bob accepted, moved to NASA HQ, and Robert Bindschadler became principal investigator of the West Antarctic ice stream project. Bob worked at NASA HQ until 1998, except for 1986–87 when Kenneth C. (Ken) Jezek (of Byrd Polar Research Center, Ohio State University) managed the polar oceans program.

Bob continued the work of his predecessor, Frank Carsey (who returned to NASA's Jet Propulsion Laboratory in Pasadena, California), and was instrumental in guiding development of algorithms for passive-microwave remote sensing, with a particular focus on sea-ice products. This ultimately led to establishing the National Snow and Ice Data Center at the University of Colorado, under the leadership of Roger Barry, as a Distributed Active Archive Center (DAAC) – the US national archive that is providing the world with sobering views of how rapidly Arctic sea ice is shrinking in response to greenhouse warming of the climate.

At NASA HQ, Bob was able to use his position as a program manager to advance glaciology. Lacking support from either the climate or terrestrial programs, Bob convinced his oceanographic colleagues to expand the polar oceans program to include glaciological research. His work led NASA to recognize the importance of the research he was funding, which led to today's cryospheric sciences program. Additionally, the funding support he provided resulted in a new generation of glaciologists becoming established.

Shortly after he arrived at NASA HQ, Bob advocated for and pushed development of the Alaska SAR Facility (ASF) at the Geophysical Institute, University of Alaska Fairbanks, for the reception and processing of synthetic aperture radar (SAR) data acquired by the European Space Agency's satellite ERS-1 (launched in July 1991), and the Canadian Space Agency's (CSA) satellite Radarsat (launched by NASA in November 1995), as well as subsequent satellites carrying all-weather day/night SARs. ASF was also established as the US DAAC for SAR data. These data, processed at ASF and elsewhere, have been crucial for the earth sciences. A new technology,

repeat-pass spaceborne SAR interferometry (InSAR), quickly evolved and has enabled highly-accurate measurement of velocity fields over vast areas of the polar ice sheets and alpine glaciers.

In exchange for launching Radarsat, NASA gained access to the data for use by US scientists. In addition, CSA agreed to twice rotate the normally right (north)-looking Radarsat temporarily so it was left (south)-looking, to enable NASA to carry out the first and second Antarctic Mapping Missions (AMM-1, 9 September–20 October 1997, and AMM-2, 3 September–17 November 2000). Kenneth Jezek was principal investigator for this large and technically-challenging project. John Crawford (of the Jet Propulsion Laboratory) and his colleagues assisted with mission planning and showed CSA how to control the orbit to obtain better interferometric data. ASF processed the resulting huge volumes of SAR data. AMM-1 resulted in the first high-accuracy spaceborne SAR-derived map of the entire Antarctic ice sheet. AMM-2 yielded the velocity field over most of the ice sheet via InSAR and speckle tracking. Both were important advances for Antarctic glaciology.

The Alaska SAR Facility, more recently renamed the Alaska Satellite Facility, continues to process synthetic aperture radar data for a broad range of scientists, including glaciologists, and continues to serve as the US DAAC for SAR data.

Bob also contributed to the shaping of the US Global Climate Change Program, and was on the science team for the ICESat laser altimetry mission. ICESat, which flew 13 January 2003–14 August 2010, provided a global, high-accuracy, spaceborne laser-derived elevation dataset for purposes that included measuring the mass balances of the ice sheets. Simultaneously, in meetings with Jay Zwally's altimetry group, Bob argued for the advantages of airborne laser altimetry after development of kinematic differential GPS which, for the first time, enabled precise aircraft positioning during long airborne campaigns for data acquisition.

Bob's management of the burgeoning polar oceans program at NASA was not just about getting the funding in place. He was also a key participant in some of the research programs. Most notable was the Program for Arctic Research and Climate Assessment (PARCA), organized and led by Bob, which had the ambitious and technically challenging goal of measuring the mass balance, then unknown, of the entire Greenland ice sheet and the physical properties of the ice sheet contributing to its mass balance.

PARCA began in 1993. Over 50 scientists participated from a broad cross-section of universities, government laboratories and other organizations across the USA. It included a

traverse around the entire ice sheet along the 2000 m contour, automatic weather stations, a shallow ice-coring program, GPS stations for measuring velocity and uplift, use of satellite data, and extensive airborne remote sensing.

The iron horse of PARCA was NASA's P-3B 4-engine turboprop Orion, which carried the Airborne Terrain Mapper (ATM), a laser altimetry/GPS-coupled system flown by Bill Krabill (of NASA Wallops Flight Facility) and his group, along with the coherent deep- and shallow-ice sounding radars developed by electrical engineer Sivaprasad (Prasad) Gogineni (of the University of Kansas) and his graduate students. The ATM measured ice surface elevations to an accuracy of 10 cm, which enabled re-measurement after 5 years to determine changes in the surface elevations. There were many. After demonstrating that his coherent radars could sound deep ice effectively, Prasad Gogineni received PARCA support, then, later, NSF support that enabled him and his graduate students to develop the most advanced ice-sounding and -imaging radars extant. Flying the ATM and the radars on the same aircraft yielded concurrent and colocated measurements of surface elevations and ice thicknesses, and a new map, including several new discoveries, of the ice sheet bed.

With his large science team, Bob accomplished his challenging and complex goal of measuring, for the first time, the mass balance of the entire Greenland Ice Sheet, including a broad suite of physical properties related to its mass balance, within 5 years. The PARCA results showed the ice sheet was changing in many ways and, overall, thinning and losing mass.

Bob retired from NASA in 1998 but continued his energetic work in polar glaciology. During 1999–2000 he continued to write and publish papers based on PARCA results. During 2001–03, he returned to the concept of force balance he had formulated in the late 1970s and applied it to explain the retreats of Pine Island Glacier in West Antarctica and Jakobshavn Isbræ in West Greenland. In 2002 Bob published, with Eric Rignot (then of Jet Propulsion Laboratory, now of the University of California Irvine), a heavily cited review paper in *Science* on the mass balances of the polar ice sheets.

When Waleed Abdalati (manager of NASA's cryospheric sciences program, 2000–04) established, in fall 2002, a cooperative project with the Centro Estudios Científicos de Valdivia (CECS, or Center for Scientific Studies, a private non-profit corporation in Valdivia, Chile, led by Claudio Bunster, winner of Chile's National Prize in Exact Sciences) – a project that included logistical support from the Chilean Navy – Bob

acted as science advisor and lead in the field. This program made measurements of ice surface elevations and elevation changes, bed elevations and ice thicknesses, using airborne surveys carried out with a Chilean Navy P-3, in conjunction with satellite laser altimetry, where Pine Island and Thwaites Glaciers enter Pine Island Bay in the Amundsen Sea.

This reconnaissance campaign resulted in a 2004 paper published in *Science* by Bob, Eric Rignot, and 10 others, showing that the Amundsen Sea ice streams are thinning and accelerating; their deep beds offer unlimited potential for irreversible retreat, and the process is most likely driven by increased basal melting of their ice shelves caused by warming ocean water, thereby reducing their buttressing effects. The campaign demonstrated the feasibility of working in the remote Amundsen Sea sector of West Antarctica, which is not characterized by pleasant weather, and encouraged NSF to fund a tight grid of radar flight lines in this region, starting in 2004, in preparation for a major study that included drilling an ice core to bedrock near the West Antarctic divide.

This work, which was followed by another NASA/CECS campaign in 2008, has continued to the present with projects such as NASA's Operation IceBridge, which is yielding evidence that irreversible retreat of the grounding lines of the major Amundsen Sea ice streams may be in progress.

During 2005–07 Bob was involved with the Intergovernmental Panel on Climate Change (IPCC); he was among the nine lead authors of Chapter 4, entitled 'Observations: changes in snow, ice, and frozen ground', in Working Group I, of the 2007 IPCC 4th Assessment Report (AR4). As such he was honored, along with the IPCC as a whole and former US Vice-President Al Gore, with the 2007 Nobel Peace Prize.

As a co-author with mathematician/oceanographer David M. Holland (of New York University) and three others, Bob published a paper in 2008, in *Nature*, on acceleration of Jakobshavns Isbræ triggered by warm subsurface ocean waters – in essence, the first solid paper on the role of the ocean in driving the Greenland ice sheet into negative mass balance.

Few people who spend more than 10 years

in the bureaucratic pressure cooker of program management are able to return to high-level research in a rapidly evolving field. Impressively, Bob accomplished that. He remained at the top of his field, working and publishing actively, long after retiring from NASA.

One might speculate that Bob's professional life was driven by a search for higher-order meaning in cryospheric science. He started as a glaciologist at a time when making maps of 'what was there' was considered sufficient purpose. Throughout his life, he far surpassed this ethos and pursued a harder path requiring bold steps and risky choices to advance glaciology. From the perspective of 2015, it is clear that Bob succeeded in navigating this harder path.

During the first half of his professional career as a glaciologist, Bob not only experienced but to a large degree led the transition of polar glaciology from local studies conducted by dog-sled with a theodolite and measuring tape to broad-scale studies of the ice sheets using modern high-resolution remote sensing technology. His approach was reflected during his younger days, when he scaled up his study of the small Brunt Ice Shelf to the huge Ross Ice Shelf, and during his later years to an even greater extent when he promoted, as a program manager, and personally brought to bear the vast high-technology resources of NASA to understand the physics of the changing Greenland and Antarctic ice sheets.

Bob Thomas was often feisty and antagonistic during scientific deliberations, but he was never false to his principles or unwilling to listen to the genuine ideas of others. He had an encouraging way with younger scientists. His legacy is not just his science or the NASA program he established, but includes the new generation of glaciologists he enabled, empowered and pushed to be the best they can be.

All of us will miss him greatly.

Craig S. Lingle and Douglas R. MacAyeal,
with contributions from many colleagues



Glaciological diary

** IGS sponsored

* IGS co-sponsored

2015

2–4 February 2015

CESM Land Ice and Polar Climate Working Group Winter Meetings

Boulder, Colorado, USA

Websites: <https://www2.cesm.ucar.edu/working-groups/pcwg> and <https://www2.cesm.ucar.edu/working-groups/liwg>

4–7 February 2015

Symposium: The evolution of mountain permafrost

Sion, Switzerland

Website: <http://www.temps-symposium.ch/program.php?language=en>

8–14 February 2015

1st European Snow Science Winter School

Sodankylä, Finland

Website: http://www.slf.ch/dienstleistungen/events/snowschooll/index_EN

13–20 February 2015

Arctic Science Partnership: Field course on Snow Covered Sea Ice

(GEOG 7400 Field Topics in Arctic System)

Nuuk, Greenland

Contact John Iacozza [john.iacozza@umanitoba.ca]

Website: <http://www.asp-net.org/content/field-schools>

23–27 February 2015

International Snow and Avalanche Course

Davos, Switzerland

Contact: Stephan Harvey [harvey@slf.ch]

Website: <http://www.igsoc.org:8000/symposia/www.slf.ch/more/training/symposia/2015/kathmandu/>

23–27 February 2015

Workshop: Measurements of ice structures by means of image analysis

Bremerhaven, Germany

Website: <http://www.awi.de/index.php?id=7415>

2–6 March 2015

****International Symposium on Himalayan glaciology**

Kathmandu, Nepal

Contact: Secretary General, International Glaciological Society

Website: <http://www.igsoc.org:8000/symposia/2015/kathmandu/>

16 March 2015

International Online Conference (webinar): New Perspectives in the Polar Sciences

Contact Rachel Downey [rachel.v.downey@gmail.com]

Website: <http://apecs.arcticportal.org/news/apecs-news>

23–26 March 2015

Workshop on the Dynamics and Mass Budget of Arctic Glaciers/IASC Network on Arctic Glaciology Annual Meeting

Obergurgl, Austria

Website: <http://www.iasc.info/nag/>

23–27 March 2015

Workshop: Dynamics of Atmosphere–Ice–Ocean Interactions in the High Latitudes

Rosendal, Norway

Website: <http://highlatdynamics.b.uib.no/www.iasc.info/nag/>

23–27 March 2015

Deutsche Physikalische Gesellschaft: DPG Spring Meeting

Heidelberg, Germany

Website: <http://www.dpg-physik.de/veranstaltungen/tagungen/>

24–26 March 2015

11th Annual Polar Technology Conference Denver, Colorado, USA

Contact: [register@polartechnologyconference.org]

Website: <http://polartechnologyconference.org/>

25–26 March 2015

Royal Geographical Society–IBG

Postgraduate Forum Mid-Term Conference

Sheffield, UK

Website: <https://www.sheffield.ac.uk/geography/phd/conference>

30 March–1 April 2015

MicroDICE conference

Microstructural evolution during HT deformation: advances in the characterization techniques and consequences to physical properties

8–10 April 2015

GLACINDIA: Stakeholder Workshop on

Identifying Climate Change Information Needs

Jawaharlal Nehru University, New Delhi, India

Website: http://www.climate-service-center.de/058047/index_0058047.html

8–10 April 2015

Polar Predictability Workshop

University of Reading, Reading, UK
Website: <http://www.climate-cryosphere.org/wcrp/pcpi/meetings/1228-seaice-reading2015>

12–17 April 2015

European Geosciences Union: General Assembly 2015

Vienna, Austria
Website: <http://www.egu2015.eu/>

20–22 April 2015

Students In Polar Research Conference

Brno, Czech Republic
Website: <http://polar.sci.muni.cz/en/news/students-in-polar-research-conference-1>

21–25 April 2015

Annual Meeting of the Association of American Geographers

Chicago, Illinois, USA
Website: <http://www.aag.org/cs/annualmeeting>

23–30 April 2015

Arctic Science Summit Week, ASSW 2015

Toyama, Japan
23–25 April: *ASSW Business Meetings*
27–30 April: *ISAR-4 and ICARP III Symposium*
Website: <http://www.assw2015.org/>

27–9 May 2015

Alpine Glaciology Meeting

Milan, Italy
Contact: Claudio Smiraglia/
Guglielmina Diolaiuti/Roberto Azzoni
<alpglaciomeet2015@gmail.com>

18–22 May 2015

‘PAST Gateways’ (Palaeo-Arctic Spatial and Temporal Gateways) Third International Conference

Potsdam, Germany
Website: <http://http/www.awi.de/pastgateways2015>

26–29 May 2015

Workshop: GIA Modeling 2015

Fairbanks, Alaska, USA
Website: <http://www.gia2015.org/>

31 May–4 June 2015

Creep 2015 conference

Toulouse, France
Contact: Maurine Montagnat <montagnat@lgge.obs.ujf-grenoble.fr>

31 May–4 June 2015

Polar Meteorology and Oceanography (49th Congress of the Canadian Meteorological and Oceanographic Society/3th American Meteorological Society Conference)

Whistler, British Columbia, Canada
Website: <http://congress.cmos.ca/>

2–5 June 2015

7th International Conference on Arctic Margins – ICAM VII

Trondheim, Norway
Contact: Tove Aune <tove.aune@ngu.no>
Website: <http://www.ngu.no/aktiviteter/7th-international-conference-arctic-margins-icam-2015>

2–5 June 2015

Workshop: Ilulissat Climate Days

Ilulissat, Greenland
Website: <http://www.polar.dtu.dk/english/Ilulissat-Climate-Days>

8–9 June 2015

International Polar Remote Sensing Workshop

Beijing, China
Contact: Xiao Cheng <xcheng@bnu.edu.cn>

8–12 June 2015

Southern Ocean Observing System (SOOS) Week

Workshop 1: Assessing the State of the Climate of the Southern Ocean
Workshop 2: Implementing a Southern Ocean Observing System
Hobart, Tasmania, Australia
Website: <http://soos.aq/news/current-news/205-soosweek>

9–11 June 2015

72nd Eastern Snow Conference: Recent Advances in Snow Remote Sensing

Jouvenne, Sherbrooke, Québec, Canada
Website: http://www.easternsnow.org/annual_meeting.html

21–26 June 2015

****International Symposium on the Hydrology of Glaciers and Ice Sheets**

Iceland
Contact: Secretary General, International Glaciological Society
Website: <http://www.igsoc.org:8000/symposia/2015/iceland>

22 June–2 July 2015

26th Union of Geodesy and Geophysics (IUGG) General Assembly

Prague, Czech Republic
Website: <http://www.iugg2015prague.com/>

22–25 June 2015

31st International Association of Sedimentologists Meeting of Sedimentology
Krakow, Poland

Website: <https://www.sedimentologists.org/ims2015www.iugg2015prague.com/>

28 June–31 July

2015 CIDER summer program: Solid Earth Dynamics and Climate – Mantle Interactions with the Hydrosphere & Carboosphere

Berkeley, California, USA

Website: <http://www.deep-earth.org/summer15.shtml>

2–4 July 2015

***SIRG – Snow and Ice Research Group New Zealand Annual Meeting**

Cass Field Station, New Zealand

Contact Wolfgang Rack <wolfgang.rack@canterbury.ac.nz>

Website: <http://sirg.org.nz/about/workshop-proceedings/>

13–17 July 2015

SCAR: XII International Symposium on Antarctic Earth Sciences

Goa, India

Website: <http://www.isaes2015goa.in/>

22–25 July 2015

PALSEA2 2015 Workshop: Data-Model Integration and Comparison

Tokyo, Japan

Contact Glenn Milne [gamilne@uottawa.ca]

27 July–2 August 2015

International Union for Quaternary Research Congress: XIX INQUA 2015

Nagoya, Japan

Website: <http://inqua2015.jp/>

16–21 August 2015

****International Symposium on Contemporary Ice-Sheet Dynamics: ocean interaction, meltwater and non-linear effects**

Cambridge, UK

Contact: Secretary General, International Glaciological Society

Website: <http://www.igsoc.org:8000/symposia/2015/cambridge/>

17–19 August 2015

Canadian Quaternary Association biennial meeting (CANQUA 2015)

St John's, Newfoundland, Canada

Website: <http://canqua2015.com/>

23–29 August 2015

Innsbruck Summer School of Alpine Research (InnsAR) on Surface–Atmosphere Exchange over Mountainous Terrain

Innsbruck, Austria

Website: <http://www.uibk.ac.at/congress/innsar/>

2–3 September 2015

***International Glaciological Society British Branch Meeting 2015**

Department of Geography, Durham

University, UK

Contact: C.R. Stokes <c.r.stokes@durham.ac.uk>

2–4 September 2015

World Symposium on Climate Change Adaptation: special session on 'Arctic climate change'

Manchester, UK

Website: <http://www.haw-hamburg.de/en/wscca-2015.html>

6–10 September 2015

6th International Conference on Polar & Alpine Microbiology

Ceské Budejovice, Czech Republic

Website: <http://polaralpinemicrobiology2015.prf.jcu.cz/pages/indexfor>

8–19 September 2015

Karthus 2015

A basic introduction to the dynamics of glaciers and ice sheets with a focus on ice-climate interactions, meant for PhD students working on (or soon to start working on) a glaciology-related climate project

Contact: Hans Oerlemans [H.Oerlemans@uu.nl]

Website: <http://www.projects.science.uu.nl/iceclimate/karthus/>

18–24 September 2015

Interdisciplinary Polar Studies in Svalbard (IPSIS) Meeting

Svalbard

Scientific Conference: Longyearbyen, 20–21 September

Field Workshops for young researchers:

Longyearbyen area, 18–19 September;

Hornsund, 22–24 September 2015

6–8 November 2015

9th Graduate Climate Conference

Woods Hole, Massachusetts, USA

Website: <http://www.graduateclimateconference.com/>

10–13 November 2015

1st Central European Polar Meeting

Vienna, Austria

Contact: Marion Rothmüller [cepm2015@polarresearch.at]

Website: <http://www.polarresearch.at/conference>

2016

20–24 June 2016

Eleventh International Conference on Permafrost (ICOP 2016)

Potsdam, Germany

Website: <http://icop2016.org>

June/July 2016

****International Symposium on Interactions of Ice Sheets and Glaciers with the Ocean**

La Jolla, California, USA

Contact: Secretary General, International Glaciological Society

2017

13–17 February, 2017

International Symposium on the Southern Cryosphere: Climate Drivers and Global Connections

Wellington, New Zealand

Contacts: Secretary General, International Glaciological Society (IGS); Secretary General, International Association of Cryospheric Sciences (IACS) (Chair of Local Organizing Committee); Director, Climate and Cryosphere (CliC)

August/September 2017

****International Symposium on Polar Sea Ice, Polar Climate and Polar Change**

Boulder, Colorado, USA

Contact: Secretary General, International Glaciological Society

2018

15–27 June 2018

SCAR/IASC Conference

Davos, Switzerland

Contact: SCAR Secretariat [info@scar.org]



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