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ICE

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Ice

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Contents

Cover picture: Khumbu Glacier, Nepal. Photograph by Morgan Gibson.

From the Editor

Dear IGS member

It is now confirmed. The International Glaciological Society and Cambridge University Press (CUP) have joined in a partnership in which CUP will take over the production and publication of our two journals, the *Journal of Glaciology* and the *Annals of Glaciology*. This coincides with our journals becoming fully Gold Open Access on 1 January 2016.

This is the biggest change that the IGS has undergone in recent decades and it will affect us in many ways. We believe it will result in an increase in paper submissions since, increasingly, many funding agencies are stipulating that papers describing research funded by them must be published in fully Gold Open Access journals. With a greater number of submissions, we are hoping that our impact factors will increase.

By definition, Gold Open Access means that the licensing associated with our publications will be CC-BY (Attribution) by default. It will be possible, however, for authors to negotiate for either a CC-BY NC SA 4.0 (Attribution – Non-commercial - Share Alike) or a CC-BY NC ND 4.0 (Attribution – Non-commercial – No Derivatives) licence. Overleaf we list the main differences of the different licences to help you understand what is involved.

In our new collaboration with Cambridge University Press we will benefit from their size and infrastructure. We will be seeing more press releases and notifications of various kinds. CUP also has a large IT department that works on online development and their IT expertise should benefit us in many ways. Since they also have a large marketing department, we can also expect to benefit from more aggressive marketing.

I want to stress that the IGS will retain full editorial control of the *Journal* and *Annals of Glaciology*. We will appoint all the editors and they will process your submissions in the same way as we have been doing, although we will be moving from using the EJ Press system to a ScholarOne system (which is the one CUP uses). For a transition period, both online submission/review systems will run in parallel.

Submissions will be two-tiered – 'Papers' and 'Letters'. There will no longer be a distinction made between 'General' and 'Instruments and methods' papers. Page charges will be replaced by Author Processing Charges (APCs). The flat rate APCs will be £1200 for a 'Paper' and £600 for a 'Letter' of 5 printed pages or fewer. If the lead author is an IGS member, they will receive a 10% discount. The APCs will be payable to CUP via RightsLink but a percentage of the income CUP receives from these (and also from hard copy subscriptions, archive subscriptions and advertising) will be passed on to the IGS.

APCs will be payable at an earlier stage in the process than page charges. At the point of supplying their final accepted files authors will receive an acknowledgement of safe receipt of their paper and an invoice via Rightslink for the APCs. Copyediting and typesetting of papers will not proceed until the APCs have been paid.

The copyediting for the *Journal* and *Annals* will from now on be done overseas rather than by a specialist house editor. It will be the responsibility of the authors and the Chief and Scientific Editors to ensure that English language standards are maintained. So please make every effort to ensure your papers are written in good English and, if necessary, get a competent English speaker to read over your paper before you submit it, especially if English is not your first language. Scientific editors will be instructed to return papers that are not written in clear English. Scientific Editors, with the help of the IGS office, will be able to put authors in touch with English language editors, if required, but the cost of these freelance services will have to be borne by the authors.

CUP is a big operation that publishes lots of journals and books and, as a result, is likely to be less flexible than our previous small in-house operation. Papers will no longer be proofread by our house editor before publication and, additionally, once a paper is online, no late alterations will be allowed. Authors will need to read and check their proofs even more thoroughly.

And that brings me to the IGS archive. In the past this has been hosted either on the IGS website or on Ingentaconnect. Typically, issues published later than 2000 have been on the Ingenta site and older papers (dating back to 1947) on the IGS site. Over recent months we have been creating XML versions from the PDFs and the resulting files have now been put onto the Ingenta site.

In due course the complete archive will be transferred to the CUP site so that all IGS material will be freely available from one location. However, this will take time and CUP is currently prioritizing setting up the IGS production procedure. It is not possible to do everything at once, so the new XML files will first go onto the Ingenta site. We are hopeful we will be able to transfer all archive files to CUP during 2016. In the meantime, the archive will be freely available from January 2016 via the Ingentaconnect site and you will no longer be required to log into our IGS 'account' to be able to view the articles. It is worth noting that it is not possible to retroactively make papers 'Open Access'; instead they will be designated 'Free'.

I would also like to draw your attention to fact the our IGS Chief Editor for over 12 years, Jo Jacka, will be retiring at the end of 2015. Jo will, however, see through to final decision all papers that have been submitted up to 31 December 2015. We are using this opportunity to rethink the chief editorship of the IGS journals. We are going to adopt an idea that Jo put forward and recruit one overall Chief Editor and three Associate Chief Editors, each assigned to a specific field of expertise. The IGS Publications Committee has drafted a couple of advertisements which are published overleaf. Please read them over and point them out to anyone you think might be a good candidate for any of these posts.

IGS Members will recently have received 2016 membership renewal reminders. Our membership rates for 2016 are unchanged from last year. Inevitably, with us going Open Access and everyone having access to our publications, irrespective of whether they are a member of the IGS or not, some will ask why bother to join the IGS. I should re-emphasize that IGS membership brings many benefits. As well as the significant APC discount for authors publishing in our journals, membership includes discounted registration fees for IGS-sponsored symposia and we have a range of quality symposia lined up. For example, the IGS is sponsoring the International Symposium on Interactions of Ice Sheets and Glaciers with the Ocean to be held in La Jolla, California from 11 to 15 July (first circular: http://www.igsoc.org/symposia/2016/lajolla/). As those who have attended will attest, our symposia are a highly enjoyable and rewarding events. They provide a unique opportunity in a relatively intimate and sociable setting to interact with peers, establish and reinforce networks and collaborations, and discuss ideas.

Only by retaining our membership will we be able to provide you with our continued service as a prestigious learned society, organizing the various symposia, meetings and workshops, collating the ICE newsletter and continuing with the prestigious Seligman Crystal and Richardson Medal awards. As an IGS member you have access to a wide network of glaciologists within which you can share your ideas and establish contacts. I will always remember how well I was received, as a young glaciologist, by John Glen, Hans Röthlisberger and John Nye, for example. When I first met Hans Röthlisberger, he noticed my IGS pin and said 'I see you are a member of the IGS,' and we were friends from then onwards. To this day I have a picture of him on my desk.

Magnús Már Magnússon
Secretary General

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Recent work

Chile

Since 2006, an increasing number of glacier-related projects have been funded, many more people been trained and, as a consequence, many more papers have been published. This ever-rising tide of glaciological research has partially been possible thanks to the larger number of government-funded projects. For example, the Chilean Water Cadastre (DGA) of the Public Work Ministry has pursued several projects, among them the preparation of the National Glacier Strategy in 2008, a route map for a better understanding of glaciers that is already under implementation. In parallel, growing public awareness of the possible impacts on glaciers of climate change or productive activities has motivated private companies and universities to invest more money in glaciology. Finally, the publication of a more strict environmental impact assessment law has forced private companies that are active near glaciers to prepare monitoring programmes, implement mitigation activities and avoid any direct or indirect glacier impacts. All the above mounting concern has been very useful for enhancing our ability to raise funds for glacier studies; however, we still have few trained people, there is no PhD programme in glaciology in Chile and we still require new and better technologies for improving our science.

In order to present the recent research advances, we invited all Chileans doing any kind of glaciological research to submit a text with their projects, including the most outstanding expeditions, results and achievements. A large number of people answered this call and submitted their contributions, illustrating in this way the great interest of the scientific community in our glaciers. Thanks to all contributors for their effort in preparing this report.

In spite of the long report list, I'm certain that many more people are doing glaciological research in the country, a large number of them from abroad. I apologize if you are one of them and were not aware of this initiative.

I'm sure this report will be informative for all members of the IGS looking for collaborators or interested in doing research in Chile. On behalf of all the contributors, I would like to welcome all of you to Chile soon.

NATIONAL PROJECTS

Glacier National Strategy

Andrés Rivera, Francisca Bown, Daniela Carrión, Sebastián Cisternas, Rodrigo Zamora, José Andrés Uribe, Pablo Zenteno (CECs), Claudio Bravo (presently at DGF) Camilo Rada (presently at University of British Columbia), Gino Casassa (presently at Geoestudios), Gonzalo Barcaza (DGA).

In 2008, the General Water Cadastre (DGA) of Chile, funded a project called the National Glacier Strategy for Chilean Glaciers. This strategy, or route map, was aimed at identifying, characterizing and assessing glaciers located in Chile, allowing their current behaviour and model future responses to climate variability and human intervention to be modelled. CECs was selected to conduct this project, which began with a review of similar strategies across the world. The strategy-approved approach was defined as a hierarchical tier glacier/climate observational system, where all Chilean glaciers can be studied in different levels of detail, from an inventory of all of glaciers existing in the country to very detailed and frequent monitoring of a few glaciers representative of the main geographical regions of the country. This strategy is being implemented, and several of the results are included in the following reports. The compilation of large quantities of glaciological data obtained so far has supported among other initiatives a new glacier law that is already in parliament.

Chilean glacier inventories

Francisca Bown, Andrés Rivera, Daniela Carrión, Dennys Caro, Pablo Zenteno (CECs), Claudio Bravo (presently at DGF), Gonzalo Barcaza (DGA).

By using recent satellite imagery, an ice surface area in Chile of ~23 000 km^2, distributed among more than 8000 ice bodies, has recently been estimated by DGA. CECs, among other institutions, updated glacier inventories in Central Chile (32°S–35°S) and in Patagonia (Cordillera Darwin and the Patagonian icefields). One of these inventories was prepared for the Río Olivares basin (33°S), where a glaciated area of 77.2 km^2 was obtained (2013), 25% less than estimated in 1955. Following GLIMS recommendations, we have delineated glacier boundaries and frontal changes all along the country, confirming a generalized retreat and thinning in response to

changing temperatures and, to a minor extent, to precipitation reduction. Frontal retreats are more significant in southern Chile, with some glaciers presenting exacerbated responses due to local conditions attributed to topographic controls, calving dynamics and volcanism. Glaciar Pío XI, together with Perito Moreno and Garibaldi, all located in Patagonia, are the only anomalous glaciers experiencing advancing fronts at present.

Revisiting the historical evidence of recent glacier behaviour in Chile: case studies from the Central and Southern Andes

F. Torrejón, A. Araneda, M. Aguayo, J. Breton, R. Urrutia (EULA – UdeC)

Ice and snow cover in the Central Andes of Chile constitute the most important reservoirs of water for agriculture and human development. However poor knowledge about the historical behaviour of glacier retreat limits a comprehensive management of these finite resources. Here we use historical written records, cartography, iconography and modern images to reconstruct glacier front behaviour from the mid-19th century to the present for glaciers Cipreses, Universidad, Queulat, Cordillera Castillo, Gualas and San Rafael (34°, 44° and 46° S). The information gathered to this day reveals a drastic glacier retreat following the last glacier maximum advance, which occurred at the end of the Little Ice Age (ca 1870 AD). However the data also clearly show a time lag in the retreat of the southern glaciers. We have estimated that, while glaciers in Central Chile started to retreat, the southern glaciers were still stable or even advancing, manifesting a time lag of approximately 30 years. A possible explanation for such differences could be changes in precipitation, associated with the fluctuations of the southern westerlies. Nevertheless a marked difference in temperature increase between the two areas is now clearly evident. Even though historical data have proved to be a very useful tool to infer past glacier behaviour there are still some uncertainties that should be refined for each specific glacier we study. Funding for this research comes from FIC Chilean Government Project 'Establecimiento de Red de Estaciones nivo-Glaciales de Cordillera de la Región de O´Higgins y Desarrollo de un modelo para la gestión integrada de los recursos hídricos de la cuenca del río Rapel' under FONDECYT grants 1120765 and 1120807 and DIUC 210.310.056-1 sp.

Understanding glacier response to climate change in Chile

Shelley MacDonell (CEAZA)

Throughout Chile and the Antarctic Peninsula, glaciers in all climate settings have shown overwhelming retreat patterns over the last few decades. It is thought that glaciers in northern Chile have been retreating in response to diminishing precipitation while glaciers in the Antarctic Peninsula have retreated due to increasing temperatures. By contrast, glaciers in central Chile, have responded to perturbations in both temperature and precipitation. Although these geographical differences have been documented we do not understand the underlying causes of such geographical variations in glacier behaviour. Developing a knowledge and understanding of these processes is critical in Chile because the glaciers are distributed over a vast latitudinal range from 18.5° S to the Antarctic Peninsula. This study aims to understand current glacier–climate relationships for different glacier settings throughout Chile, and to use this understanding to predict future glacier responses to climatic changes. To address the principal aim, this study is using mass and energy balance models at three sites, each with differing climatic signals along a latitudinal gradient. The first site, the Tapado glacier, is situated in northern Chile and is a cold-based glacier that experiences a cold, dry climate. The Universidad glacier is situated in central Chile and is a temperate glacier. This site is on average warmer than the other two sites. Finally, the Ecology glacier on King George Island near the Antarctic Peninsula represents a cold and wet location. Meteorological data from each site will be used to drive an energy- and mass-balance model to understand both glacier–climate interactions and ablation rates from each glacier type. The project started in late 2013 and will conclude in 2016. This project is supported by the Chilean National Science and Technology programme (FONDECyT 11130484).

Climatology of Andean glaciers

Esteban Sagredo (PUC), Thomas Lowell (University of Cincinnati)

We systematized, classified and identified the spatial distribution of the climates that permit the occurrence of present-day glaciers in the climatically diverse Andes. A first approximation suggests that a sample of 234 Andean glaciers exists under three distinctive combinations of temperature and precipitation conditions: (a) cold and dry, (b) intermediate and (c) warm and wet conditions. Cluster analysis and principal component analysis of temperature, precipitation and humidity reveal seven climatic configurations that support present-day Andean glaciers and suggest that these configurations have a distinctive geographical distribution. The groups are: (1) inner tropics and Tierra del Fuego, (2) wetter outer tropics, (3) drier outer tropics, (4) subtropics, (5) central Chile–Argentina (semi-arid), (6) northern and central Patagonia and (7) southern Patagonia.

This classification provides a basis to examine the spatial variability of glacier sensitivity to climate change, to unravel the causes of past glacial fluctuations, to understand the climatic signals driving present-day glacier fluctuations and perhaps to predict the response of glaciers to future climate changes.

Sensitivities of the equilibrium-line altitude to temperature and precipitation changes along the Andes

Esteban Sagredo (PUC), Summer Rupper (Brigham Young University), Thomas Lowell (University of Cincinnati)

We applied a full surface energy- and mass-balance model to quantify ELA sensitivity to temperature and precipitation changes across the range of climate conditions found in the Andes. Model results showed that regional climate conditions modulate ELA sensitivity to large-scale climate perturbations, revealing strong spatial variability in the sensitivities of the equilibrium line altitudes to temperature and precipitation changes. We find that ELAs respond linearly to changes in temperature, with the magnitude of the response being prescribed by the local lapse rates. In contrast, ELA sensitivities to precipitation changes are nearly linear and are inversely correlated with the emissivity of the atmosphere. Whereas ELA sensitivities to temperatures are greatest in the inner tropics; precipitation becomes more important in the subtropics and the northernmost mid-latitude regions. This study provides a mountain-range-scale framework for interpretation of past climate changes as recorded by glaciers. These modelling results provide a framework for understanding and comparing past episodes of glacial fluctuations across the Andes and ultimately for predicting glacier response to future climate changes.

Energy and mass balance in glaciers of Central Chile, the Lake District and Patagonia

Andrés Marangunic, Ana María Marangunic, Gino Casassa, Gabriela Collao, José Becerra, Cristián Peralta, Martín Bustamante, Cedomir Marangunic (Geoestudios)

As part of a project for Chile's water authority (DGA), the energy balance and mass balance of Yeso and Bello glaciers in the Maipo Valley (33° S), Mocho-Choshuenco Glacier (40° S), Exploradores Glacier (46° S) and Tyndall Glacier (51° S) were studied in 2013. Several automatic weather stations were deployed on the glaciers, with real-time data transmission via iridium. Results included energy balance calculations, glaciological mass balance and a lahar risk assessment at Mocho-Choshuenco Volcano.

Recent technological improvements on Chilean glacier monitoring

Sebastián Cisternas, José Uribe, Andrés Rivera (CECs) David Ulloa (Unmanned Ltda)

New technologies developed in recent years have made possible better glacier monitoring in Chile. Efforts have been achieved primarily in terrestrial photogrammetry based on non-metric fixed cameras aiming to study glacier ice flow, distributed albedo via digital cameras and meteorological data transmission by using radio and satellite technologies. Daily ice flow rates up to tens of metres have been obtained when Patagonian glaciers were surveyed, including Jorge Montt (Southern Patagonian Icefield), Colonia and Nef (Northern Patagonian Icefield). In these glaciers, ice velocities were estimated by developing computational routines and continuous photographic series captured by fixed autonomous cameras (Canon EOS series). Fixed cameras have also been considered a useful alternative for monitoring distributed albedo over glacier areas, based upon reflectance values stored in the camera photographs. In order to enhance the usefulness of fixed cameras as a monitoring tool, a photograph transmission, preprocessing and remote management system was designed and implemented, including, among others, synchronization using GPS time. This allowed a theoretical transmission range of 20 km, with UHF repeaters, 3G phone networks and, more recently, through the iridium system.

Development of an airborne mapping system

Jens Wendt (deceased), Anja Wendt (presently at Bavarian Academy of Sciences), Andrés Rivera (CECs), Maximiliano Fuentealba, Roberto Silva (Chilean Air Force).

The CECs Airborne Mapping System (CAMS) system concept began in 2005 as an initiative brought up by the geodesist Dr Jens Wendt (deceased). The CAMS's goal was to obtain digital elevation information of glaciers and, by repeating the survey, to determine glacier volume changes. The laser technology is a sophisticated tool of elevated cost. Hence the CAMS development consisted of the in-house integration of off-the-shelf elements that compose the whole system. At the beginning the system was formed by four sensors: a lidar Riegl LMS Q240, an inertial measurement unit iMar iNav-FMS, a double frequency GPS Javad Legacy and a camera Canon EOS 5D. In 2011 a thermal camera FLIR SC620 was added. The first trial flights were done using fixed-wing aircraft – DHC-6 Twin Otter, Piper PA-30 Twin Comanche, among others. Subsequently, in 2012 the system was prepared for the certification to be mounted and operated on a helicopter platform (Eurocopter AS350 B3 Ecureuil). The first expedition was

carried out in December 2006 in the National Park Torres del Paine in the Chilean Patagonia, where Glacier Tyndall was flown over to basically test the operation under field conditions. Since then, the system has been used extensively, obtaining remarkable results, as for example, at Hudson volcano recording comparative data of an eruptive event that occurred in October 2011. Surveying expeditions have been performed at both Patagonian icefields (Southern and Northern), Villarrica Volcano, High Basin of Olivares River (Central Chile) and Huasco Basin (Northern Chile).

Airborne radar developments for temperate ice measurements

José Andrés Uribe, Rodrigo Zamora, Andrés Rivera (CECs) Gino Casassa (presently at Geoestudios), David Ulloa (Unmanned Ltda)

A low-frequency airborne radar system was developed at 1 MHz central frequency for measuring temperate ice. The system uses a 5 kV impulse transmitter, a receiver with variable gain (80 dB maximum) and an acquisition system working at 100 MHz of sampling frequency. The antenna system consists of a 150 m long resistive loaded transmitter dipole and an 80 m long resistive loaded receiver monopole, deployed at the rear of a CASA 212 aircraft. The monopole ground is the aircraft structure and the separation between transmitter and receiver antennas is 50 m. The aircraft also carries a laser altimeter, an inertial navigation system, a digital camera and a geodetic GPS receiver. The first tests were performed in 2006 and 2008 at Tyndall glacier, where a thickness of 670 m was detected. A large number of side returns also appeared in the data, which can be confused with bedrock returns. Simulation of side returns can discriminate bedrock echoes from side returns. Other two low-frequency helicopter-borne radar systems were developed, with central frequencies of 20 MHz and 50 MHz respectively. The 20 MHz system is employed in deep temperate ice and the 50 MHz system is used in high-altitude small glaciers. These systems use a 3.2 kV impulse transmitter, a variable gain receiver of 60 dB maximum and a 400 MHz acquisition system with 14 bits of resolution. The antenna is a rectangular metal structure that hangs 20 m below the helicopter and contains two resistive loaded bow-tie antennas, receiver and transmitter respectively, where the metal structure acts as a reflector. The complete antenna structure for the 20 MHz system weights nearly 350 kg and the antenna structure for the 50 MHz systems weights 150 kg. Several survey measurements are been performed in Central Chilean Andes and North Patagonian Icefields in 2012 and 2013, where a thickness of 800 m was detected in San Rafael glacier.

Airborne radio echo sounding of glaciers in Northern Chile, Central Chile and the Lake District

Gino Casassa, José Luis Rodríguez, Andrés Marangunic, Ana María Marangunic, José Becerra, Martín Bustamante, Gabriela Collao, Cedomir Marangunic (Geoestudios)

As part of a project for Chile's water authority (DGA), ice thickness and water equivalent of 18 glaciers spanning a latitudinal range from 28° S to 41° S were studied in 2013. A helicopter-borne radar was used, designed by Norbert Blindow (Germany). For cold glaciers in northern and central Chile a hanging antenna of 50 MHz was used, while in the Lake District an antenna of 25 MHz was preferred. Preliminary results show thicknesses shallower than 100 m in the small mountain glaciers of northern and central Chile, with a maximum of several hundred metres on some of the ice-capped volcanoes in the Lake District.

GASS

Andrés Rivera (CECs), Gonzalo Barcaza (DGA), Christophe Kinnard (CEAZA, presently at Université du Québec), Carlos Cárdenas (UMAG), Ricardo Jaña (INACH), Bruce Molnia (USGS), US Embassy Santiago.

Under the USA–Chile Environmental Cooperation Agreement, the USA and Chile are working together to improve our understanding of how changing glaciers will affect Chile's water resources. With support from the US Department of State and expertise from the US Geological Survey, we are developing a Glacier Monitoring Network bringing together government and academic researchers from Chile, the USA and other partners in the region to share data and glacier monitoring technology and identify priority glaciers for additional research. The main aims are to (1) demonstrate new technology for monitoring glaciers and (2) improve the accuracy of water resources data by installing new technology at strategically important glacier sites to collect sensor-based mass balance data with micro-environment weather parameters. Thanks to this initiative, which began in 2011, five glacier ablation sensor system (GASS) units built by the Virginia Institute of Technology were donated to Chilean institutions (CEAZA, DGA, CECs, UMAG and INACH), which installed each unit on a frequently visited glacier. Two workshops have taken place, facilitating the exchange of scientific and technical information on glacier and water resources management between the USA and Chile. They provided a forum for the discussion of glacier monitoring strategies that assist in predicting long-term water storage and availability.

Andean Climate Change Interamerican Observatory Network (ACCION)
Mathias Vuille (University of Albany), Andrés Rivera, Francisca Bown (CECs).
The retreat of glaciers and consequent decreased water availability in response to ongoing climate change is a major concern for Andean countries, especially for those that are more economically and socially vulnerable. Because of this, a new cooperation initiative led by the University of Albany in collaboration with research institutions from Chile, Ecuador, Perú and Bolivia began in 2011. A first ACCION meeting took place in February 2012, with the aim of launching the programme devoted to enhance capacity building and strengthen climate change research in the Andean region. The ACCION programme is expected to provide a sustainable network of local scientists and stakeholders who will transfer forthcoming knowledge to policy makers. The three main topics of ACCION are education from the scientists up to the policy makers' level, training of young researchers and public dissemination aimed to reach national governments, population segments, economical actors, water managers and decision makers. The most recent meeting took place in November 2013 in Quito, Ecuador, where first results were presented. One of the main outcomes expected at the end of the programme in 2014 is the publication of a glacier mass balance manual in Spanish.

NORTHERN CHILE (18–31° S)

Recent research in arid zones of northern Chile by CEAZA
Christophe Kinnard (presently at Université du Québec, Canada)
In 2006, CEAZA initiated a glaciology programme to study the relationship between climate, the hydrological cycle and the productive sector in arid zones (more research detail given below). Located on the fringe of the hyperarid Atacama Desert, CEAZA's research originally sought a better understanding of the dynamics and hydrological contribution of these high-altitude glaciers. As concerns arose from both the public and Chilean authorities regarding the fate of some of these glaciers surrounding mining projects, an extensive study was undertaken to monitor glaciers and possible adverse mining impacts. Much was learned about glacier and energy mass-balance, areal changes and their hydrological contribution. Mean mass loss rates varied from 0.5 to 1.5 m w.eq. a^{-1} (2003–2011) while glaciers have shrunk by an average of ~29% over the period 1955–2007. Declining precipitation is thought to be the primary driver of mass loss. Glaciers in the high and dry Andes are subject to intense solar radiation, high winds and low humidity, driving substantial sublimation losses from snow and ice surfaces, often the dominant glacier ablation process. Strong winds also drive blowing snow sublimation, as well as snow trapping downwind from ridges, an important process contributing to glacier formation. Research activities in 2009 shifted toward Tapado glacier (30°08′ S 69°55′ W) in the upper Elqui valley, focusing on mass and energy exchange processes over the surfaces of penitentes and on the interactions between glacier melting and rock glaciers, which frequently buttress glaciers in this part of the Andes. In 2011, we began studying Glaciar Universidad (34°40′ S, 70°20′ W) in central Chile, the largest glacier outside Patagonia, by combining lidar surveys to energy and mass balance modelling, learning about the current and future state of glaciers in this region.

Mass balance modelling and water discharge from glaciers in northern and central Chile
Shelley MacDonell (CEAZA), James McPhee, Maximiliano Rodríguez (UCh), Sebastián Vivero (CEAZA), Francesca Pelliciotti (ETH-Zurich), Michal Petlicki (CEAZA), Marco Carenzo (ETH-Zurich)
In the basins of the Elqui and Maipo rivers it is possible to identify hundreds of white, debris-covered and rock glaciers. In semi-arid areas, these ice bodies are potentially important reservoirs of fresh water. However, the response of these ice bodies to variations of current and future climate is unknown, as is the current level of contribution of melting ice to the flow of the main river basins in the regions. The Glaciology Group at the Centro de Estudios Avanzados en Zonas Áridas, with support from the Department of Civil Engineering at the University of Chile, is investigating (1) the mass balance and water discharge of Tapado, San Francisco, Bello, Yeso and Pirámide glaciers, (2) the surface dynamics of the Tapado and Llano de las Liebres rock glaciers and (3) the discharge of water from the Las Tolas rock glacier. The study will better understand how these ice bodies respond in relation to climatic conditions as well as their importance in regional hydrological cycles. This is intended to advance the national knowledge about the nature of water reserves associated with ice masses and potential future responses.

Development of snow and ice penitents in relation to their impact on surface meltwater production from snow and ice in the semi-arid Andes.
Lindsey Nicholson (University of Innsbruck), Shelley MacDonell (CEAZA)
Penitentes are widespread in the semi-arid Andes but their measurement is problematic

because of difficult access and complex surface topography, precluding evaluation of 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 over time.

Modelling the current and future hydrological contribution of glaciers and seasonal snow in semi-arid mountain catchments

Christophe Kinnard (CEAZA, presently at Université du Québec), Stefaan Lhermitte (CEAZA, presently at Katholieke Universiteit Leuven), Simon Gascoin (CEAZA, presently at CESBIO), Shelley MacDonell (CEAZA), Jakob Abermann (CEAZA, presently at Asiaq)

Snow and ice surfaces in semiarid mountain regions are critical for controlling water availability downstream. Climate change is expected to cause a rise in air temperature and to enhance aridity in these regions, which would profoundly affect the mass balance of glaciers and seasonal snow and their respective contribution to stream flow. Regions where meteorological, glaciological and nival observations are scarce represent a challenge for determining the present contribution of snow and ice to stream flow, and even more for forecasting future conditions under climate change scenarios. This project aims to estimate the present and future hydrological contribution of seasonal snow and glaciers in a typical high-altitude catchment of the semiarid Andes in the Norte-Chico region of Chile (26° S–23° S) using a modelling approach constrained by existing and new field observations. The largely ungauged catchment 'La Laguna' in the upper Elqui Valley (30° S, 70° W) is used as the main test site for model development, validation and application. This catchment drains into the La Laguna reservoir, which is used for controlling water allocation for agriculture irrigation downstream. Thus there is a high interest in developing modelling tools to improve our knowledge of seasonal and longer-term water storage in snow and glaciers and to better forecast meltwater input to La Laguna reservoir on a seasonal basis.

Characterization and monitoring of rock glaciers in the Elqui River catchment and mass balance of the Tapado Glacier

Christophe Kinnard (CEAZA, presently at Université du Québec), Sébastien Monnier (CEAZA, presently at PUC Valparaiso), Shelley MacDonell (CEAZA), Jakob Abermann (CEAZA, presently at Asiaq), Michal Petlicki (CEAZA)

A glaciological, hydrological and geomorphological measurement programme aims to understand the behaviour and hydrological importance of glaciers and rock glaciers in La Laguna sub-basin of the Elqui River through field activities from late November 2011 to mid-April 2012. The glaciological mass balance was applied on Tapado glacier. A negative mass balance was found for the 2011/12 hydrological year (–0.981 m w.eq.). Glacier topographic measurements made with a terrestrial laser system (lidar) enabled the construction of a digital terrain model (DTM) at 1 m spatial scale and high vertical accuracy (10 cm). The DTM obtained from lidar was compared with an existing DTM from 2010 to calculate the geodetic balance of the ablation zone (–4.4 m w.eq. $(2\ a)^{-1}$). Measurements of glacier movement in Tapado revealed little motion, in the order of 2–5 $m\ a^{-1}$. The energy balance was calculated using data from two automatic weather stations, one in the ablation zone (4769 m a.s.l.), and the other in the accumulation (5527 m a.s.l.). Monitoring of flow in the vicinity of Tapado glacier showed that the ice can contribute 7% of flow entering the La Laguna reservoir during a typical day in February. Geophysical measurements on rock glaciers suggest the presence of a core of massive ice in the top of the rock glacier Llano de las Liebres, and a heterogeneous mixture of sediment, water and ice at the terminus. In the Tapado complex, a massive ice thickness of 50–70 m was estimated. The thickness and content ice decreases up to 20–230 m from the transition between the debris-covered and rock glacier to the front of the rock glacier below. The thermal monitoring of rock glaciers show that the variation of the surface temperature can be explained by variations in altitude, potential solar radiation and duration of snow cover.

Glacier mass balance and regional snow conditions in the Norte Chico: interaction with the climate and its influence on mass loss

Christophe Kinnard (CEAZA, presently at Université du Québec), Stefaan Lhermitte (CEAZA, presently at KU Leuven), Simon Gascoin (CEAZA, presently at CESBIO), Shelley MacDonell (CEAZA)

The primary objective of this project was to implement a comprehensive monitoring programme of a high mountain glacier in the semi-arid Norte Chico region, where knowledge of the glacial climate relationship is scarce. The results of the integrated monitoring programme provided new information about the influence of climate processes on glacier behaviour, in particular the generation of melt water and its influence on flow conditions (annual discharge, steady flow). This study was based at the Tapado glacier, and work included: the installation of three meteorological stations, including a permanent off-glacier station,

the development of a mass balance stake network, the first surface energy-balance calculations from the basin, and preliminary predictions of how this glacier might respond to future climatic changes. This project served as the foundation project for several other studies working in the upper Elqui basin.

From snowfall to streamflow: a modelling approach to assess the water budget of Norte Chico upper catchments

Simon Gascoin (CEAZA, presently at CESBIO)

Norte Chico area relies strongly on water resources from mountain areas. Streamflow and groundwater recharge are dominated by the annual snowmelt from the high altitude areas in the Andes Cordillera. A better knowledge of snow cover and snowpack dynamics can help water managers to forecast water availability and sharing among water users (mainly agriculture and mining). Despite the scarcity of the water resources and its importance for the regional development, many aspects of the Norte Chico's hydrology remain unexplored. Previous studies have shown that even the first principle of hydrology, the water balance equation, is difficult to resolve given the available data. The objectives of the project were (1) the modelling of this critical branch of the Norte Chico's hydrological cycle: from snowfall to streamflow, (2) the study of the physical processes at play and (3) the assessment of the climate change impact on water resources. This project has allowed developing a methodology to map precipitation across the Norte Chico territory, identifying atypical precipitation events characterized by inversion of the precipitation gradient and better understanding wind interplay with the water cycle of the high-Andean catchments.

Glacier monitoring at the Pascua-Lama mining project

Daniela Carrión, Dennys Caro, Sebastián Cisternas, Thomas Loriaux, Camilo Muñoz, Flavia Burger, Jorge Hernández, Francisca Bown, José Andrés Uribe, Jonathan Oberrauter, Ryan Wilson, Andrés Rivera, (CECs), Javier Corripio (Meteoexploration, CECs)

A monitoring programme was started in 2011 in the high altitude arid zone of Pascua Lama (30° S), including three glaciers (Guanaco, Estrecho and Ortigas 1) and four glaciarets (Toro 1, Toro 2, Esperanza and Ortigas 2), with the aim of analysing potential glacier dynamics in relation to nearby mining activities. This monitoring is accomplished through five main lines of research: (1) glacier mass balance based upon the measurement of 127 stakes, terrestrial and aerial lidar survey, differential GPS and satellite imagery; (2) energy balance by means of automatic weather stations and time-lapse cameras, (3) summer glacier streamflow measurements; (4) supraglacial and intraglacial dust concentration monitoring by means of dust collectors and ice drilling; and (5) monitoring of permafrost distribution through the use of thermistors, including measurements of the 'active layer' depth and temporal variations in the thermal gradient. This glacier monitoring programme has been requested by the National Environment Authority, which can approve or cancel the gold mine project, depending on the detection of possible direct or indirect human-induced impacts on nearby glaciers.

CENTRAL CHILE (31–37° S)

A glaciological baseline for the upper Olivares basin

Thomas Loriaux, Andrés Rivera, Sebastián Cisternas, Camilo Muñoz, Flavia Burger, Jorge Hernández, Dennys Caro, Francisca Bown, José Andrés Uribe, Guisella Gacitúa, Jonathan Oberrauter, Rodrigo Zamora, Roberto Silva, Jeppe Malmros, Ryan Wilson (CECs)

A glacier monitoring research programme funded by mining companies began in 2012 at the Olivares hydrological basin (33° S), aiming to complete a glaciological baseline, including glacier mass, energy and hydrological studies. The studied glaciers are considered the main source of runoff used in the country's capital (Santiago, 6.7 million inhabitants), for human consumption, agriculture and other economic activities especially during dry summers. We have focused on two glaciers (Olivares Alfa and Beta) by installing, among other instruments, three automatic weather stations, a mass balance network of stakes, two automatic photographic cameras for monitoring albedo changes and two runoff stations. We have also surveyed five glaciers using our airborne radar and lidar systems, allowing mapping ice surface and subglacial topographies at different seasons. The collected radar ice thickness data (maximum ice thickness of 223 m) allowed a total volume of water equivalent to be calculated of 3 km^3 storage within 5 main glaciers. GPS survey of several stakes resulted in surface ice velocities between 1 and 5 m a^{-1}. Mass balance studies showed high summer ablation, with an important role of sublimation (penitentes as high as 1.5 m). Runoff contributed by Olivares Alfa glacier averaged 461 L s^{-1} between January and April 2013 with peaks of up to 2000 L s^{-1}, confirming the importance of glacier meltwater during the summer months (January–March).

Ice-debris landforms and mountain permafrost of Central Chile

Alexander Brenning (University of Waterloo), X. Bodin, G. Azócar (PUC)

A field-based monitoring programme on rock glaciers and periglacial environments in the Andes of Santiago and Upper Elqui valley, partly as contract research for the Chilean Water Directorate (DGA). Active layer depths ranged between 2.5 and 8 m, and horizontal surface velocities between 32 and 67 cm a^{-1} have been observed on rock glaciers. A geodetic mass balance of the debris-covered Pirámide glacier in the Andes of Santiago (~34° S) revealed an average annual loss of ~1.1 million m^3 w.eq. between 1965 and 2000 (J. Torres, collaboration with J.-L. García, Catholic University, Santiago), supporting observations of ice loss in debris-covered glaciers in the nearby Punta Negra area (X. Bodin, A. Brenning). The utility of satellite-based thermal inertia mapping to characterize the thermophysical properties of ice-debris landforms was furthermore explored through a collaboration between M. Peña (now at Universidad Alberto Hurtado) and A. Brenning. A first statistical estimation of the distribution of mountain permafrost in the Chilean semi-arid Andes between ~29° S and 32° S was prepared at the University of Waterloo. For this purpose, 1075 intact and 1664 relict rock glaciers were inventoried, partly based on an inventory previously prepared for the DGA. The results suggest that permafrost can be potentially present in >2600 km^2, considering a permafrost index ≥0.5 and excluding steep bedrock. Moreover, the result suggests that the occurrence of mountain permafrost is nearly continuous above ~4500 m a.s.l. and discontinuous between ~3900 and 4500 m a.s.l. Public concern regarding impacts of mining on rock glaciers in the Andes has led to a review of possible future impacts on these ice-debris landforms as well as their current political and legal situation.

Glacier–rock glacier transitions in shifting mountain landscapes: peculiar highlights from the Central Andes of Chile

Sébastien Monnier (PUC Valparaiso)

Rock glaciers in the semi-arid (central) Andes of Chile are important reservoirs of solid water and are potential contributors to the hydrological cycle. For a long time, rock glaciers have fascinated researchers because of their structure and genetic significance, leading to the so-called debate 'rock glacier controversy'. The basis of our research is the possible direct transition between glaciers and rock glaciers that may occur when mountain geomorphological landscape is shifting in response to global/regional environmental change. In the central Andes of Chile we observe various striking features where a rock glacier is seen being currently developing in the continuum of a glacier or a debris-covered glacier. We aim to study these cases of current glacier–rock glacier transitions, which have barely been reported in the literature and express important landscape and environment modifications in context of climate warming (especially preservation of glacial ice in further periglacial domain). Our hypothesis states that the observed features exhibit a fast rhythm of development (decades–centuries), that a structural continuity exists between the upper glacier part and the lower rock glacier part and that permafrost conditions are developing in the ground. We aim, over 3 years, to inventory these current glacier–rock glacier transition systems (between 30 and 35° S) by selecting three sites, studying their detailed surface morphology and evaluating their development and morphological evolution, investigating their internal structure and monitoring their ground thermal conditions. To achieve these goals, we want to use remote sensing methods, luminescence dating methods, ground-penetrating radar and in situ geodetic and thermal monitoring. The results of the research programme are expected to bring important insights not only into the understanding of rock glacier signification and genesis but also into the general evolution of mountain landscapes, the modifications of the cryosphere and the conservation of solid water in a high mountain catchment.

Hydrochemistry of glacierized catchments in central Chile

Alfonso Fernández (Byrd Polar Research Center, UdeC), Bryan Mark (Byrd Polar Research Center)

We have begun preliminary analysis of geochemical data from stream water, snow and glacier ice from the Andes of Santiago, more specifically in the Cerro Plomo (33.25° S and 70.22° W). Samples were taken in 2013 during an expedition led by Kurt Sanderson, who was supported by the American Alpine Club and Nikwax (more details at http://chileglacierquest.com/). The purpose of this survey was to establish a baseline of fundamental geochemical characteristics of the water draining the Olivares valley. The goal is to test hypotheses about relative influences of climate, elevation and bedrock geology on water geochemistry. They are using different techniques such as ion chromatography and mass spectrometry to analyse those samples for standard chemical properties such as water isotopes, major dissolved cations and anions, and nutrients. These characteristics of the water relate to factors such as precipitation sources,

percentage of meltwater feeding streams and local geology. Coupled with ongoing glacier–climate modelling, mapping of previous glacier extents using satellite imagery, and subsequent fieldwork, these initial samples will be fundamental to understanding whether and how much snow and glacier ice contributes to water availability changes. First results indicate that those samples plot in between the Chilean Meteoritic Water Line and the Global Meteoritic Water Line, and there is clear elevation dependency in both oxygen and deuterium depletion.

Ice thickness and water volume estimations in central Chile using radio-echo sounding.
Guisella Gacitúa, José Andrés Uribe, Jonathan Oberreuter, Rodrigo Zamora, Andrés Rivera (CECs)
Several glaciers have been surveyed in recent years in the Andes, by using helicopter-borne radars working at different transmission frequencies. In May–July 2011, a long-range expedition covered eight glaciers of three main river basins in central Chile (Aconcagua, Maipo and Rapel). Data collection was performed under the project 'Ice volume estimations in Central Chile' requested by the General Water Directorate (DGA) of the Chilean Government. In this opportunity, terrestrial radar (5 MHz) measurements were complementary to aerial measurements (25 MHz) reaching a maximum depth of 304 m (Cortaderal Glacier, 34°38′ S 70°18′ W, in Rapel Basin). In July 2012, 12 glaciers feeding the river basins of Maipo and Rapel were surveyed with the same purpose under a new proposed project of the DGA ('Ice volume estimations using radio-echo sounding in central Chile'). Ice thickness and volume water equivalent estimations were obtained using data collected from an helicopter-borne system working at 20 or 50 MHz. In May 2013 five glaciers of the Olivares basin were prospected using 50 MHz. In this study, good coverage of the glacier area allowed us to characterize better than in earlier studies the subglacial base, whose valleys are typically U-shaped with marked slope at the borders. Average ice thicknesses range for these glaciers from 57 to 116 m with a maximum measured of 248 m. Their total water volume estimation resulted in 3.06 ± 0.37 km^3.

Glacier studies in central Chile related to environmental impact assessment studies.
Cedomir Marangunic (Geoestudios), Paula Marangunic (deceased), Andrés Marangunic, Ana María Marangunic, José Becerra, Gabriela Collao, Gino Casassa (Geoestudios)
Several projects have been were performed in central Chile (33° S to 34° S) within the period 2006–2013 for environmental impact assessments of mining and hydroelectric companies. In Chile environmental regulations have become stricter in recent years. Studies have included glacier inventory, glacier variations, mass balance, energy balance, hydrological balance and glacier stability.

Rock glacier studies in Chile
Francisco Ferrando (UCh)
Several rock glacier studies have been conducted in the central Andes in collaboration with glaciologists from the Universities of Denver and South Carolina. These studies include a classification of rock glaciers, characterization of glacier dynamic in response to climate change, rock glacier water contributions and possible impacts of mining activities on rock glaciers. Several outreach activities have been conducted in order to discuss environmental impacts of productive activities on rock glaciers and permafrost.

LAKE DISTRICT (37–41° S)

Ice–volcano interactions and risk assessment associated with ice-capped volcanoes
Andrés Rivera, Francisca Bown, Rodrigo Zamora (CECs), Jorge Clavero (Presently at UMAYOR), Benjamin Brock (Northumbria University), Javier Corripio (Meteoexploration, CECs)
The ice–volcano interactions and the impacts of geothermal heating and eruptive activity on glaciers located on top of active volcanoes in Southern Chile (37–46° S) have recently been studied. Until a few years ago, it was believed that ice shrinkage in this region was mainly related to climatic changes, but there are different glacier behaviours depending on the intensity and type of volcanic activity, as well as on the geothermal influx of volcanic activity at their bases. For instance, strombolian to plinian eruptions in the second half of the 20th century have partially affected and even completely destroyed glaciers existing within calderas, whereas geothermal heat fluxes have a direct incidence on basal ablation as well as on the mass and hydrological balances. Ice crevassing is also a direct consequence of eruptive events and an interesting object for research in relation to ice dynamics. These non-climatic glacier responses could have dramatic consequences for the population living in the vicinity of volcanoes, so this project aimed to improve and extend the survey by means of satellite remote sensing and airborne and field campaigns. The total glacier area located on top of the main 26 active volcanoes in the study area is ~500 km^2. Glacier area reductions have ranged from 0.07 km^2 a^{-1} at Mentolat, a volcano with one of the smallest ice caps, to a maximum of 1.16 km^2 a^{-1} at Volcán Hudson. There are also contrasting glacier–volcano interactions

such as the abnormal ice frontal advances at Michinmahuida, following the Chaitén eruption in 2008, and the rapid melting of the Hudson intracaldera ice following its plinian eruption of 1991. Several airborne lidar and radar surveys have been conducted at these volcanoes, including the use of thermal infrared cameras (FLIR) and visible vertical photogrammetry. The net effect of climate changes and volcanic activity are the negative mass balances, ice thinning and glacier area shrinkage.

Volcán Villarrica edifice deformation in response to deglaciation

Jens Wendt (deceased), Anja Wendt (presently at Bavarian Academy of Sciences), Andrés Rivera (CECs), Jorge Clavero (Presently at UMAYOR).

A network of GPS stations installed on rock in the surrounding of the main cone of Volcán Villlarrica (39° S) have been measured since 2003. This network has been repeatedly surveyed with dual frequency GPS receivers in order to detect deformations of the main edifice. The main idea is to detect the unloading effect of deglaciation on the volcanic cone. The results obtained until 2010 were promising, but the M8.8 Maule earthquake that affected the country in 27 February of that year completely changed the vertical and horizontal trends. Since 2010, three new campaigns have been conducted that will allow the impacts of the earthquake to be distinguished from the unloading long-term trends.

Biological analysis of firn/ice cores in the Chilean Lake District

Pamela Santibáñez (Montana State University), Shiro Kohshima (Kyoto University), Rodrigo Scheihing (deceased), J. Jaramillo (UACH), Takahiro Shiraiwa, S. Matoba (Hokkaido University), R. Silva, D. Kanda (National Institute of Polar Research, Japan), Editha Elias, Alejandra Urra, Pedro Labarca (CECs), Gino Casassa (presently at Geoestudios)

Glacial regions were believed to be devoid of life until the early 1990s, when microbial life was proved to exist in glacial environments. Biological analysis of three shallow firn/ice cores was reported from the summit and at 2000 m a.s.l. of Volcán Mocho-Choshuenco (39˚55′ S, 72˚02′ W), and the summit of Volcán Osorno (41˚06′ S, 72˚30′ W). This study focused on the potential use of microorganisms as proxies of net mass balance in firn/ice cores from temperate glaciers. Seasonal signals of microalgae, testate amoebae and pollen was demonstrated. This study concluded that biological analyses of firn/ice cores provide reliable annual and seasonal markers to date and estimate past net mass balance in these temperate glaciers. In addition, this research documented for the first time the presence of testate amoebae on glaciers. Three of the four taxa, *Trinema lineare*, *Trinema enchelys* and *Puytoracia bergeri*, have previously been reported in ice-free environments. The fourth taxon corresponds to a new species named *Puytoracia jenswendti* nov. sp. to honour Dr Jens Wendt. The testate amoebae found in the firn/ice cores display clear seasonal variations in abundance, indicating that these records can provide a novel proxy for estimating past glacier mass balance. Additionally, two related undergraduate theses (CECs–UACH) have not yet been published in scientific journals, but they represent a baseline for future studies. One described the spatial distribution of microalgae on the Mocho-Choshuenco Glacier and the other presented a phylogenetic analysis of *Chlamydomonas* and *Chloromonas* genera from the same site.

PATAGONIA AND TIERRA DEL FUEGO (41–56° S)

Fluctuations of the Última Esperanza ice lobe (52°S), Chilean Patagonia, during the last glacial maximum and termination 1

Esteban Sagredo (PUC), Patricio Moreno (UCh), Rodrigo Villa-Martínez (CEQUA), Michael Kaplan (University of Columbia), Peter Kubik (ETH-Zurich), Charles Stern (University of Colorado Boulder)

We developed a record from the Última Esperanza region (51°25' –52°25' S), SW Patagonia, to unravel the temporal and spatial structure of glacial fluctuations during T1, in the only windward-facing continental landmass in the Southern Hemisphere that intersects the core of the southern westerly wind belt. Geomorphic, stratigraphic and geochronological evidence indicate the following stages during and since the Last Glacial Maximum: (1) deposition of prominent moraine complexes during at least two advances dated between ~39 and N17.5 ka; (2) development of an ice-dammed proglacial lake (glacial lake Puerto Consuelo) accompanying ice recession; (3) active deposition of moraine complexes at intermediate positions followed by recession at ≥15.2' ka; (4) lake level drop and subsequent stabilization between 15.2 and 12.8 ka; (5) a glacial readvance in glacial lake Puerto Consuelo between 14.8 and 12.8 ka; (6) ice recession, stabilization and lake-level lowering between 12.8 and 10.3 ka; and (7) glacial withdrawal and disappearance of glacial lake Puerto Consuelo prior to 10.3 ka. By comparing our results with the chronologies from neighbouring regions we explored whether there is a consistent temporal/geographical pattern of glacial fluctuations during the LGM and T1, and examined their implications at regional, hemispheric and global scales. The correspondence of these variations with key

paleoclimate events recorded in the Southern and Northern Hemispheres suggest a common forcing that most probably propagated through the atmosphere. Regional heterogeneities at millennial timescales probably reflect the influence of processes related to deep ocean circulation, and changes in the position/intensity of the Antarctic polar front and southern westerly winds.

Equilibrium-line altitude since the Last Glacial Termination in Río Tranquilo glacier (47° S), Central Patagonia

Esteban Sagredo (PUC), D. Ward (University of Cincinnati), M.A. González (PUC), T.V. Lowell (University of Cincinnati), M.A. Kelly (University of Columbia) and Juan Carlos Aravena (CEQUA)

The goal of this ongoing research is to estimate the equilibrium line altitudes (ELA) associated with the most prominent glacial advances occurred since the Last Glacial Maximum at Tranquilo valley (47° S). Geomorphic evidence indicates that glaciers that today occupy the headwalls of Río Tranquilo valley expanded during at least three different periods since the last glacial termination, leaving a complete record of former glacial positions. Moraines associated with these major glacial advances have been preliminarily dated at ~13.0 ka, 5.4 ka and 150 a BP (cosmogenic and tree-ring ages). Based on glacial geomorphic mapping and the application of a glaciological model (GC2D), we are attempting to reconstruct the former glacial surface and estimate the changes in the ELA for these major episodes of glacial advances. This study represents the first effort to quantify the magnitude of glacial fluctuation for the entire time interval between the last glacial termination and the present for a single glacier site in South America.

Reconstructing the extent of the former Patagonian ice sheet

Juan Luis García (PUC), Brenda L. Hall (University of Maine), Michael R. Kaplan, Joerg Schaefer (Columbia University), Rodrigo M. Vega (UACH)

During recent years, a research project has focused on unravelling the timing, structure and duration of the last glacial period in the Torres del Paine region (51° S, Chile). This work, together with a previous study in the Archipelago de Chiloé, has encompassed a detailed mapping of the glaciological landforms and sediments together with the construction of detailed geomorphological maps. For both studied areas we used a stereoscopic analysis of aerial photographs that resulted in preliminary maps that then were extensively ground-tested. Prominent moraine arcs occur within the main island of Chiloé and Torres del Paine that delineate the former extent of the ice sheet. We use ^{10}Be exposure cosmogenic and ^{14}C radiocarbon to constrain the age of these landforms. For ^{10}Be, we sample the top surface of well-preserved boulders embedded in moraines and obtain the age of the associated glacial advance. For ^{14}C, we core mires and peat bogs using a piston core, which provides us with a minimum age for glacial retreat. In the lab, we spike our ^{10}Be samples with a low-background ^{9}Be carrier, which, together with accelerator mass spectrometer high-level currents, allows us to produce a precise glacier chronology. Our work in the Torres del Paine and Chiloé regions has provided a new basis for redefining the limits of the Patagonian ice sheet at two distant areas south of 41° S during the last glacial period. Main findings suggest a glacial expansion at 26 000 calibrated ^{14}C years before present (a BP) in Chiloé and an earlier local LGM during the Marine Isotope Stage III (e.g. 30 000–60 000 a BP) with an ice extent twice the size of that previously assumed for Torres del Paine. A prominent late-glacial expansion throughout the Antarctic Cold Reversal period (e.g. 14 200–12 500 a BP) interrupted the last deglaciation in south Patagonia.

Pleistocene and Holocene glacial variations in Central Patagonia, Chile: Geomorphological evidences

María Mardones, Blanca Gana (UdeC)

We have studied geomorphological evolution and glacial fluctuations during Holocene and Pleistocene times in the Aysen river basin, Central Patagonia. We mapped glacial distribution and type and glaciofluvial and proglacial reliefs through a morphological and morphometric filed survey in 2005–07, sedimentological studies at the University of Concepción (Chile), construction of stratigraphic columns, geomorphological interpretation of aerial photos and ^{14}C AMS radiometric dating at the Beta Analytic Laboratory Inc., USA, of organic sediments within moraine, fluvial and lacustrine sediments. Seven representative complex glacial cold events, successively arranged from east to west, have been recognized. The four oldest events, located in the eastern Pampas, predate the last glaciation; a frontal moraine system has been dated from the Last Glacial Maximum; whereas the complex closest to the Precordillera moraine and those located in the Main Cordillera have ages consistent with the Late Glacial, early and middle Holocene Neoglacial.

Glacial geomorphology and Holocene glacier reconstruction in Sierra Baguales, Patagonia

José Araos (UCh, CEQUA), Jacobus Le Roux (UCh)

The paleogeographic evolution of the southern section of the Andes can be linked to glaciations of different ages and extensions. Following the Pleistocene, the development of alpine glaciation

in the mountains and fluvioglacial valleys established the Patagonian relief, which still presents evidence of ancient glacial processes. The dynamics of effluent glaciers for the Southern Icefield after 18–10 ka and their relation to the latitudinal displacement of the belt of westerly winds have been widely studied. However, there are still information gaps regarding the spatio-temporal dynamics of alpine glaciers close to the Patagonian Icefield and the climatic variables that conditioned their dynamics. Such is the case in the Sierra Baguales, located 50 km north-east of the Torres del Paine National Park. The study area is located in the zone of influence of westerly winds but topographically isolated from the Southern Ice Field. The accumulation zone of ancient glaciers was at ~1000 m and more than 200 km from the Pacific coast. The aim of the research is to carry out detailed mapping of the glacial geomorphology in order to reconstruct the paleosurface ice cover, estimating changes that occurred in the glaciers, and consider the climatic characteristics that determined the dynamics and extent of these glaciers. Radiocarbon dating will be used to estimate the timing of the withdrawal and eventual advance of glaciers, so that their behaviour can be compared with other studies in different glaciers of southern Patagonia.

Mid-Holocene glacier response to climate conditions in Patagonia.

Claudio Bravo (DGF, CR2), Maisa Rojas (DGF, CR2).

This work corresponds to an evaluation of glacier cover and climate conditions during the mid-Holocene (MH, 6000 a BP) as compared with pre-industrial times (PI, 1750 AD) in Patagonia. For climate conditions, temperature and precipitation monthly data from Paleoclimate Modelling Intercomparision Project Phase II (PMIP2) models were compared. Glacier mass balance was based on daily data from the same PMIP2 models. Hence regional equilibrium line altitude (ELA) was obtained for both periods. Glacier response to climate conditions shows a 15–25 m lower ELA during the MH in comparison to PI. These differences could imply significant changes in glacier area considering the hypsometry and that the value is a climatological ELA. Because of this difference, significantly colder temperatures are attributed in DJF, MAM and JJA during the MH in concordance with changes in insolation and the fact that mid-latitude glaciers are more sensitive to temperature change than to precipitation changes. This result agrees with some moraine ages associated with the mid-Holocene.

Glacier fluctuations study using dendroglaciological methods in southern Chilean Andes.

Juan Carlos Aravena (UMAG), Brian H. Luckman University of Western Ontario), Andrés Rivera (CECS).

The most relevant results obtained in our dendroglaciological research programme between 2006 and 2013 concern three study areas: Monte San Lorenzo, Isla Santa Inés and Glaciar Jorge Montt. Monte San Lorenzo (47°35′ S, 72° 21′W) is an isolated granitic massif located 70 km to the east of the southern limit of the Northern Patagonian Icefield and is the third highest summit (3706 m) in the southern Andes. We study the history of glacial fluctuations over the last few hundred years in this area, using dendroglaciological, geomorphic and historical (documentary, photographic) evidence. The methods included dating moraines and other glacial landforms in three glacial valleys to develop individual and site chronologies of glacier fluctuations over the last 400 years. The glaciers of the Monte San Lorenzo area (Calluqueo, Río Tranquilo and Arroyo San Lorenzo) all have massive, nested, lateral moraines that were formed during or prior to the 1600s. We also examine the local Holocenic glacier fluctuations in Santa Ines Island (53°45′ S, 72°30′ W) in the western portion of the Strait of Magellan close to its exit to the Pacific Ocean, using dendroglaciological, geomorphic and historical evidence. Santa Ines glacial advances have well-defined, clearly separated frontal moraines dating from the late 1600s, around 1800, 1860, 1910, 1930 and 1960. Glaciar Jorge Montt (48°20′ S/73°30′W, Southern Patagonian Icefield), has experienced a recession of 19.5 km between 1898 and 2011. This retreat uncovered trees buried during the Little Ice Age (LIA) advance of the glacier. Samples of these trees were dated using radiocarbon methods, yielding burial ages between 460 and 250 calendar years BP. The dendrochronology and maps indicate that Glaciar Jorge Montt was at its present position before the beginning of the LIA, in concert with several other glaciers in Southern Patagonia, and reached its maximum advance position between 1650 and 1750 AD.

Recent geomorphological studies (20th century) of ice fronts from the Northern Patagonia Icefield

María Mardones, Mauricio Aguayo, Ernesto Smith, José Luis Breton (UdeC)

Glacier fluctuations and geomorphic effects in proglacial areas have been investigated in the last hundred years for the Northern Patagonia Icefield. We studied Gualas, San Quintín, San Rafael, Grosse, Exploradores, Leones, Colonia-Arco and Steffen glaciers. We have studied their evolution

over the past 50 years by comparing regular cartography, aerial photographs, recent Google Earth images and evidence from a field survey in November 2012. Widespread and simultaneous withdrawal is revealed, from 1870 (end of the Little Ice Age) to the present, although the eastern slope glaciers show a delay of 10 years in relation to the NW side. Glacier emissaries recording larger changes in the past century are San Rafael and Los Leones glaciers (4.8 and 4.6 km respectively). There is also concordance between small cold events recorded between 1920 and 1940 (some disagreements appear to be related to lack of records rather than the event itself) and also in retreat of glaciers fronts occurring in the mid-1990s. The geomorphic effects of this rapid glacier retreat can be summarized as follow: moraine disintegration, proglacial, intraglacial and juxtaglacial lake formation, and formation of alluvial plains and terraces associated with GLOF/IDLOF discharge.

Recent glacier changes in the Northern Patagonia Icefield (NPI)

Andrés Rivera, Rodrigo Zamora (CECs), Daniela Carrión, Sebastián Cisternas, Thomas Loriaux, Camilo Muñoz, Flavia Burger, Jorge Hernández, Francisca Bown, José Andrés Uribe, Jonathan Oberrauter, Jeppe Malmros (CECs) Anja Wendt (presently at Bavarian Academy of Sciences)

Several glaciological methods have been used, including remote sensing, applied geodesy, radio-echosounding, photogrammetry and oceanographic measurements in order to highlight recent changes in the calving glaciers Nef, Colonia and San Rafael in the NPI. Successive airborne lidar surveys have allowed surface topography changes in recent years to be estimated (high thinning rates at both, accumulation and ablation areas). Using airborne radar data, we have mapped the subglacial topography and computed the ice volume storage in these glaciers. Fixed photographic cameras have been installed in front of all these glaciers, allowing the detection of ice velocities and surface and dynamic changes. Water-level pressure sensors were also installed in glacier-related lakes, where GLOFs were detected as well as high ablation rates during the summer. The analysis of the obtained results showed a steady trend of the retreating and thinning processes in comparison with previous studies.

Monte San Lorenzo: glacier inventory and recent glacier fluctuations.

Daniel Falaschi (IANIGLA), Claudio Bravo (DGF), Mariano Masiokas (IANIGLA), Ricardo Villalba (IANIGLA), Andrés Rivera (CECs)

Monte San Lorenzo (47°35' S, 72°18' W) is located on the boundary between Chile and Argentina in southern Patagonia. This is the first glacier inventory for this area combining research from both countries. The inventory was developed using a combination of ASTER and Landsat ETM+ images from 2005 and 2008. We catalogued 213 glaciers, covering (2005–08) a total area of 207 km^2 and between 520 and 3700 m a.s.l. Based on all available information we determined an 18.6% reduction in the total glacier area since 1985. Larger valley glaciers account for a major part (32%) of the total area reduction and glacier fragmentation has occurred in 50% of the ice bodies larger than 1 km^2. Results agree with the generalized pattern of glacier retreat observed throughout the Patagonian Andes.

Outburst floods from Cachet2 glacial lake, NPI

Alejandro Dussaillant (University of Greenwich), Claudio Meier (UdeC), Varyl Thorndycraft (RHUL), Gerardo Benito (CSIC), Wouter Buytaert (ICL), Walter Bertoldi (UTrento), Brian Reid (CIEP)

Since the renewed cycle of outburst floods (OF) in the Colonia valley began in 2008 after four decades, studies have been ongoing. These have included: (1) estimation of peak flows using glaciological, hydrological, hydraulic and palaeoflood methods, e.g. yielding 4000 $m^3 s^{-1}$ for the Oct 2008 event; (2) monitoring of the flood waves down the deglaciating valley since 2010 using an array of TD sensors that detected a fast flood wave >4 m high; (3) estimating morphological impacts, including flood–sediment–vegetation interactions, combining field rtkGPS surveys and analysis of aerial photography and satellite imagery including ASTER, showing high erosion/deposition, significant reductions on dense floodplain vegetation, and simplified channel morphology; and (4) palaeoflood studies in the Baker river downstream to extend the flood record, which have already found evidence of past floods of over 10 000 $m^3 s^{-1}$. As of December 2013, more than a dozen OF have occurred in the Colonia–Baker system since 2008, which together with other studies done in the area suggest an accelerated hydrological (and sediment) regime. This is particularly relevant given the US$4 billion mega-dams hydropower project planned for the area (HidroAysén) and the relevance of downstream river and fjord ecosystems for local livelihoods. Research being planned includes analysing effects on the fjord ecosystem, estimations of bedload via modelling and DEMs of difference to hopefully estimate potential reservoir silting (and dam feasibility), and development of modelling tools for flood hazard assessment for communities and potential infrastructure as well as ecological impacts, to take into consideration changing glacial and river system scenarios.

Oceanographic and glaciological survey in Glaciar Jorge Montt

Carlos Moffat (COPAS, UdeC).

Jorge Montt glacier is one of the fastest retreating glaciers in the Patagonian Icefields. Fieldwork to understand the impact of glaciological and oceanographic processes on glacier retreat started in February 2010 with a joint pilot fieldwork effort that included UdeC, the University of Washington (UW) and CECs researchers, and has continued since then. It was followed by eight field campaigns spanning all seasons between January 2011 and November 2013 funded by FONDECYT-Chile. Field efforts have also included the installation of a weather station in the proglacial fjord to monitor atmospheric temperature, barometric pressure and precipitation as well as wind velocity and direction, and oceanographic moorings to monitor the evolution of sea level, water properties and ocean currents. In March 2013, this rich dataset was augmented by the collection of seven sediment cores during a joint UdeC–UW cruise to investigate the recent history of retreat and sediment deposition in the fjord. Key results from these efforts are a first-order understanding of the hydrographic structure and circulation associated with the freshwater discharge from the glacier, which includes a multi-layered summer outflow severely constricted by a shallow sill at the mouth of the fjord; significant seasonal changes in the structure and magnitude of the freshwater outflow; and the strong modulation of the inflow of oceanic water towards the ice by local wind forcing. Analysis of the data is ongoing, with particular focus on mixing processes, the history of sediment deposition and the coupling between calving events and oceanographic variability in synoptic time-scales. These research efforts will continue through a new grant (2014–16) involving researchers from UdeC, UW and CECS. This research was funded by the COPAS Sur-Austral programme and Fondecyt-Chile Grant #11100362. Francisca Bown, Andrés Rivera, Chuck Nittrouer, Katie Bodlt, Bernard Hallet and Claudio Iturra all contributed to this research.

Ice–ocean interactions in Southern Patagonia

Francisca Bown (CECs), Carlos Moffat (COPAS, UdeC), Andrés Rivera, Tobias Kohoutek, Jonathan Oberrreuter, Guicella Gacitúa, Sebastián Cisternas (CECs), Claudio Bravo (presently at DGF) , Michelle Koppes (UBC), Bernard Hallet (UW), Richard Sylwester (Northwest Geophysical Services)

We have carried out several glaciological/oceanographic studies near tidewater glaciers in Patagonia, including among others, Glaciar San Rafael (46°40′ S), Glaciar Jorge Montt (48.47° S) and Parry Fjord at Cordillera Darwin (54°44′ S). The main aim of this long term programme, is studying glacier dynamic role in determining sediment yields. Also, we are aiming to understand present-day ice dynamics in response to local-scale oceanographic and topographic factors. Our survey programme is mainly based on satellite remote sensing, airborne lidar, feature tracking techniques, fjord bathymetry, sediment sample studies and water-level pressure measurements. Fixed cameras have been installed at San Rafael, Jorge Montt and Pío XI glaciers, where ice velocities, and calving fluxes have been studied. Among the most outstanding results obtained so far are the very high ice velocities measured at Jorge Montt glacier, where a mean maximum of nearly 24 m d^{-1} was detected in 2010. The programme also included bathymetric surveys using a Bubble Pulser system able to detect water depth (a maximum of 400 m was detected at Jorge Montt glacier fjord) and subaquatic sediments (up to 100 m thick). Thanks to the ongoing CECs–UdeC–UW collaboration and forthcoming grants, we hope to extend the Bubble Pulser surveys to other Patagonian fjords, where new cameras, water pressure sensors and AWSs will be installed.

Controls on sediment yields from tidewater glaciers from Patagonia to Antarctica

Bernard Hallet (UW); Michele Koppes (UBC); John Anderson, (RiceU); Julia Wellner, U. Houston; Rodrigo Fernandez (INACH and RiceU); Cristián Rodrigo (SHOA), Andrés Rivera (CECs)

This project has been performed in glaciers of Patagonia and Tierra del Fuego and their respective fjords with the aim of assessing the role of glacier dynamics in determining glacial sediment yields through a combination of techniques and resources from glaciology and marine geology. Field work included glaciers in the Antarctic Peninsula as well. The major finding from this work is that sediment yields and erosion rates decrease by two orders of magnitude between the temperate glaciers of Patagonia (San Rafael, Europa and Marinelli) and the polar glaciers of the Antarctic Peninsula, and that this decrease is a function of the presence of meltwater, and not of ice flux.

Annual water balance of the Glaciar Exploradores drainage basin, Chilean Patagonia

Takane Matsumoto (CIEP), Norifumi Sato (Kaihatsu Koei Co., Ltd.).

The annual water balance for a drainage basin containing Glaciar Exploradores, a maritime outlet glacier from Northern Patagonia Icefield, Southern Chile, was calculated for a water year from 1 April 2005 to 31 March 2006. The result shows that a total of about 6300 mm entered the basin with about 3100 mm of meltwater and about 3200 mm of rainwater, 96% of which water was drained by a river. Water storage in this basin decreased from

late autumn to early spring. From mid-spring to mid-autumn, water storage increased with large rainfall contributions and tended to decrease at other periods, even including midsummer. The averaged total ablation over Glaciar Exploradores during the same period was estimated from the result of water balance as about 4700 mm. The averaged total accumulation would have been around 4000–5000 mm because the area of the glacier has not shown distinct changes for the recent decades.

Spatial distribution of rock glaciers in the central Patagonian Andes

Takane Matsumoto (CIEP), Masafumi Aoyama (Japan Map Center), Fabien Bourlon (CIEP)

Nearly 150 rock glaciers have been identified in the Andes of central Patagonia between 44° S and 49° S in Chile and Argentina. The east–west precipitation gradient in this region is quite high becausee of the orographic effects of persistent mid-latitude westerlies, and the distribution of these rock glaciers is restricted to a narrow zone along 72° W with a semi-arid climate, between the mountain ranges with their maritime climate and the present glaciers including the Northern Patagonia Icefield in the west and the arid plain (the Patagonian Desert) in the east. Terminus positions are generally around 1600–1800 m a.s.l. The bedrock geology in this zone consists mainly of Jurassic–Cretaceous volcanics and sediments. All three types of activity status – active, inactive and fossil rock glaciers – are distributed over the zone and most of them are glacier-derived and tongue-shaped glaciers in periglacial environments superimposed on earlier glacial landscapes.

Influence of deciduous forest on snow surface heat balance in central Chilean Patagonia

Takane Matsumoto (CIEP), Katsuhisa Kawashima, Tsutomu Iyobe (Research Institute for Natural Hazards and Disaster Recovery)

The influence of forest on accumulation and ablation of snow has never been studied in South America although deciduous and coniferous forests are widely distributed in the snowy areas of southern Chile and Argentina. We carried out glaciological and meteorological observations in an open field and a forest of deciduous southern birch (lenga: Nothofagus pumilio) at Portezuelo Ibáñez (46° 04′ S, 72° 02′ S, 1110 m a.s.l.) in the Región de Aysén, central Chilean Patagonia during September and October 2013, in order to clarify influences of the forest on surface heat balance of snow cover. Global solar radiation and wind speed in the forest were 34% and 32%, respectively, of those in the open field in an average, whereas air temperate and relative humidity were almost the same at both sites. The average melting heat in the forest was 47% of that in the open field which was 57.8 W/m^2.

Snow stratigraphy and mass balance at the Northern Patagonia Icefield

Andrés Marangunic, Gino Casassa, Ana María Marangunic, Gabriela Collao, Cristián Peralta and Cedomir Marangunic (Geoestudios)

As part of a project for Chile's water authority (DGA), in 2013 Geoestudios led a project to study the surface mass balance on the plateau of the Northern Patagonia Icefield (San Rafael, San Quintín and Colonia glaciers). Two 10 m masts were deployed on the icefield, equipped with air and snow thermistors and snow height sensors. GPR measurements at 200 MHz were performed, reaching depths of 50 m at the most. A strong reflector at 10–50 m was detected, interpreted to correspond to the water table. Field measurements were due to continue in 2014.

Quantifying mass balance processes on the Patagonian Icefields

Marius Schaefer (UACH), Horst Machguth (Technical University of Denmark), Mark Falvey (UCh), Gino Casassa (Geoestudios)

By means of a combined climatological-surface–mass-balance modelling approach, geodetic mass balances and different velocity measurements, for the first time the different contributions to the mass balance of the Patagonian Icefields have been quantified. Between 1975 and 2011, the Northern Patagonian Icefield accumulated 15.9 Gt a^{-1} of snow on average (corresponding to 4.02 m w.eq. m^{-2}). Average melt of snow and ice was 16.6 Gt a^{-1} (4.21 m w.eq. m^{-2}) in this period. Calving losses increased strongly from 1.60 Gt a^{-1} in 1975–2000 to 3.13 Gt in 2000–09. On the Southern Patagonia Icefield (SPI), average yearly accumulation of snow in 1975–2011 was 61.3 Gt of snow (4.90 m w.eq. m^{-2}) and average melt was 33.4 Gt a^{-1} (2.67 m w.eq. m^{-2}). Calving fluxes on the SPI were estimated to have increased from 40.1 Gt a^{-1} in 1975–2000 to 59.9 Gt a^{-1} in 2000–11.

Ground penetrating radar studies of Martial glacier, Ushuaia, Argentina

Rodrigo Zamora (CECs), Rodolfo Iturraspe (CADIC).

In 2009, Martial Glacier near Ushuaia in Argentina was surveyed using of ground penetrating radar (GPR). A GSSI GPR unit combined with a 400 MHz monostatic antenna was used to collect the data. The objective of the survey was determining the ice thickness and the internal structure of the glacier. Preliminary results show that the glacier thickness ranged between 10 and 50 m. In spite of some clear bottom reflections, in several profiles it was difficult to interpret the

bottom reflections due to the steep and rough bedrock, as well as due to the presence of water bodies within the glacier. Most of the glaciers in the eastern margin of Tierra del Fuego show significant changes in the last decades, indicating a general recessive process in the area.

High-resolution airborne gravity-radar observations of glaciers in Patagonia

Eric Rignot (University of California Irvine–JPL), Andrés Rivera, José Uribe, Rodrigo Zamora (CECs)

The Patagonian icefields, the biggest temperate ice bodies in the Southern Hemisphere, have experienced important areal shrinkage and thinning in recent decades, significantly contributing to sea-level rise. Among the main driving factors behind this retreat are atmospheric warming in recent decades inducing higher melting rates, and equilibrium line altitude (ELA) upward migration. Ice dynamics also play an important role, especially in many Patagonian glaciers that calve into deep fjords or lakes. Several recent works have measured ice velocities by using GPS, feature tracking and interferometric techniques; however, ice thickness is still barely known and, in spite of several on the ground radar measurements, this variable remains the great missing part of the equation, especially when ice thickness is greater than 600 m or where the glacier surfaces are very crevassed, or near the ELAs, where measurements on the ground are logistically difficult. In order to better understand glacier dynamics, the Gordon and Betty Moore Foundation is supporting a research project aiming to estimate glacier mass balance based upon ice fluxes determined near ELAs by means of airborne measurements. Three field campaigns have been conducted so far to the Patagonian Ice Fields since 2012, including an airborne gravity (AIRGrav), low-frequency radar and lidar. These systems were mounted on helicopters, providing a high-resolution and high-precision data of ice thickness and surface topography of several glaciers in the Northern and Southern Patagonian Icefield.

Mass balance estimations from ice core data collected in the Southern Patagonia Icefield

Margit Schwikowski (Paul Scherrer Institut), Andrés Rivera (CECs), Gino Casassa (presently at Geoestudios)

A 50 m (33.24 m w. eq.) ice core was collected in 2006 from the accumulation area of Pío XI glacier (49° S, 73°21' W, 2600 m a.s.l.) the biggest of the Southern Patagonia Icefield (SPI). The SPI is the largest temperate ice body in the Southern hemisphere outside Antarctica and has been divided in more than 48 glaciers, several of them calving into fjords on the western maritime margin and into freshwater lakes on the eastern, more continental side. Most the SPI glaciers have been thinning and retreating in recent decades; however, there are a couple of exceptions, the most remarkable being the strong advance of Pio XI since early 1960. The ice core collected from the upper reaches of Pio XI glacier near the continental watershed divide allowed net accumulation rates to be derived for the period 2000–06. Borehole temperatures indicate near-temperate ice but the average melt was only 16 ± 14%. Records of stable isotopes are well preserved and were used for identification of annual layers. Net accumulation rates range from 3.4–7.1 m w.eq., comparable to precipitation amounts on the Chilean coast but not as high as expected for the Icefield. Ice core stable isotope data correlated well with upper air temperatures and may be used as a temperature proxy. The man aim of this project was to study the recent mass balance of this remote and poorly studied area.

ANTARCTICA

Subglacial Lake Ellsworth (SLE) exploration (2006)

Andrés Rivera (CECs), Jens Wendt (deceased), Rodrigo Zamora (CECs), David Ulloa (Unmanned Ltda.), Guillermo Neira, Luis Araya (Chilean Army).

In January 2006, a scientific traverse was conducted from Patriot Hills (80°18′ S 81°30′ W) to Subglacial Lake Ellsworth (SLE, 79°00′ S 90°20′ W) in West Antarctica. The main aim of the campaign was studying the geophysical characteristics of SLE and its surroundings. For that purpose, dual frequency GPS was used to measure the surface topography of the ice, as well as ice velocities at stakes deployed along the track. A 150 MHz central frequency ice-penetrating radar was used to measure ice thicknesses. Along the transect we measured the surface topography, finding a maximum altitude of ~2000 m at the ice divide; ice velocities from 35 m a^{-1} 100 km east of the divide to ~2 m a^{-1} near the divide; and ice thickness of 3185 m above SLE. The campaign had the logistic support of the private company Antarctic Logistics and Expeditions (ALE).

Scientific traverse to East Antarctica between December 2007 and January 2008

CECS and Chilean Army

CECs in collaboration with the Chilean Army and the private company Antarctic Logistic Expeditions organized a scientific traverse from Patriot Hills (80°18' S 81°22' W) to the Antarctic Plateau during the summer 2007/08. The objective was the collection of data allowing to determine ice characteristics and dynamics. Furthermore, we

aimed to study recent changes and to contribute to reconstruction of Antarctic climate variability. The expedition covered a total distance of 2400 km with a total traverse time of 40 days. Ice thickness, snow accumulation radar and gravity data were collected during the traverse. Nineteen stakes out of the 53 installed in 2004 were found and re-measured by dual frequency GPS. Surface snow sampling for biological analyses and study of morphology of megadunes in relation to local patterns of snow accumulation were done during the traverse. An exploration of subglacial lake Recovery D (85°S 21°E) was also carried out with the aim of assessing ice dynamics and subglacial hydrological conditions in relation to fast flowing ice.

Airborne survey of the Antarctic Peninsula and West Antarctica, October 2008

CECS, NASA and Chilean Navy

During October–November 2008 an airborne Antarctic campaign was performed from Punta Arenas in Southern Chile, following flight lines surveyed over the Antarctic Peninsula and Amundsen Sea Glaciers in 2002 and 2004. On board the Chilean Navy P3, a laser altimeter, ice penetrating radar, inertial navigation system, GPS receivers and real-time navigation system were installed. Data allowed the measurement of ice thickness and surface topography variations comparing previous data.

Glacial geomorphology in the South Shetlands

Francisco Ferrando (UCh)

Quaternary geomorphology and recent glacier behavior studies were conducted in the South Shetland Islands in collaboration with Brazilian researchers. The main aim was to study glacier dynamics in response to global warming by means of sedimentological, geomorphological and remote sensing studies. These studies included the analysis of climatic and environmental variability in the South Shetland Islands and the Antarctica Peninsula using marine and lacustrine sedimentary records.

Glaciological and meteorological investigation at Fleming Glacier, Antarctic Peninsula

Anja Wendt (presently at Bavarian Academy of Sciences), Francisca Bown, Rodrigo Zamora, Andrés Rivera (CECs), Jens Wendt (deceased), Claudio Bravo (presently at DGF), Gino Casassa (presently at Geoestudios), Jorge Carrasco, Juan Quintana (Dirección Meteorológica de Chile)

The project aimed to investigate the behaviour and recent evolution of Fleming Glacier, southern Antarctic Peninsula, and its relation to the retreat of Wordie Ice Shelf. Optical and radar satellite data have been used to map the ice shelf and to measure the glacier velocities during the last few decades. After the disintegration of Wordie Ice Shelf in the 1980s, Fleming Glacier had completely lost its floating ice tongue by the early 2000s. Ice-flow velocities at the glacier were found to have increased by 20–60% between 1989 and 2010. Three field campaigns were carried out between 2007 and 2009 to install an automatic weather station and a continuous GPS station at Fleming Glacier and to perform an airborne lidar survey as well as to collect glaciological field data. A comparison with airborne laser scanning data acquired in joint campaigns of NASA, CECs and the Chilean Navy in 2002 and 2004 revealed surface lowering along a longitudinal profile from an elevation of 1100 m down to the ice front where maximum elevation change rates of about -4 m a^{-1} were detected. Negative ice elevation trends together with the acceleration of the ice flow indicate that Fleming Glacier has not yet reached a new equilibrium and is still losing mass through enhanced ice flow.

Union Glacier, Ellsworth mountains: a new gate for exploring the interior of West Antarctica, 2008–10

Rodrigo Zamora, Andrés Rivera, José Andrés Uribe, (CECs).

During December 2008, 2009 and 2010, CECs and the private company Antarctic and Logistic Expeditions conducted traverses of Union Glacier, Ellsworth Mountains, West Antarctica, with the aim of studying glacier dynamics, the subglacial topography and crevasses. A 400 MHz GPR was used to detect hidden crevasses within the ice; a 150 MHz ice depth radar collected the ice thickness data, yielding maximum thicknesses of 1600 m, defining a subglacial topography well below sea level (~800 m).

Oversnow traverse to the Antarctic Plateau (2014)

Andrés Rivera, Rodrigo Zamora, José Uribe (CECs)

A new oversnow traverse was conducted by CECs in January 2014, from Union glacier (80° S) toward the high West Antarctic Ice Sheet, where the triple ice divide between Institute, Rutford and Pine Island Glaciers is located. The area has been poorly surveyed, in spite of recent research carried out on nearby Subglacial Lake Ellsworth. We were looking for the internal structure of the ice and the subglacial topography, especially for evidence of possible ice-divide migrations among these glaciers. The campaign received the logistic support of the private company Antarctic and Logistic Expeditions. The tractor convoy included a brand new scientific research module, built in Sweden, especially designed for this campaign. This module will serve as a mobile station for this 5 year research programme. A maximum ice thickness of nearly 3200 m was detected along

the traverse of more than 100 km. A complex subglacial topography was detected, much deeper than previously estimated by BEDMAP2.

***Para*-ICE: towards a better understanding of calving events.**
Michal Pętlicki (CEAZA), Christophe Kinnard (CEAZA, presently at Université du Québec), Jakob Abermann (CEAZA, presently at Asiaq)
The project para-ICE is designed to improve our understanding of ice calving, focusing on mechanisms and forcing. During two intensive field expeditions (2013, 2014) to the Antarctic Peninsula, calving events have been monitored using a novel combination of different methods. The core of the programme is a sequence of high-resolution terrestrial laser scans (TLS) of calving glaciers at two sites near the Chilean Antarctic Station Gabriel González Videla. These have been complemented with video-imaging of the calving fronts in order to provide a continuous record of individual calving events. By relating calving volume derived from the calibrating a statistical model and relating the results of TLS surveys to a quantitative analysis of the video sequences, we will for the first time be able to provide a detailed and continuous record of calving activity for tidewater glaciers. In this way, a complete catalogue of individual calving events within the time frame of the field campaign is being produced. This project is supported by INACH.

Radar development for cold ice measurements
José Uribe, Guicella, Gacitúa, Rodrigo Zamora, (CECs), David Ulloa (Unmanned Ltda.)
Two types of radar have been developed by CECs in order to measure ice thickness and snow accumulation in cold ice. One system is pulse-compression radar, with a central frequency of 155 MHz, 20 MHz of bandwidth and 200 W of peak power, which is aimed at ice-thickness measurements with a resolution of 4.2 m in ice. The second system is a frequency-modulated–continuous-wave (FM-CW) radar, with a frequency range between 550 and 900 MHz, 21 dBm of power and a maximum range of 480 m. This radar is aimed at obtaining snow accumulation measurements in cold ice with a maximum resolution of 0.5 m. The ice thickness radar uses two Yagi antennas, and the snow accumulation radar uses two (transmitter and receiver) wideband log-periodic antennas. The pulse-compression system uses two chirps: 1 µs chirp for shallow ice and 10 µs chirp for deep ice sounding. Both radars can operate simultaneously without interference between them, which allows simultaneous high-resolution mapping of the first few hundreds of meters of surface snow/firn layers and bedrock detection. Several ground-based measurements were performed in 2008 and 2009 at Union Glacier, West Antarctica, using the pulse-compression system, and in 2010 with both systems also at Union Glacier and nearby glaciers. During these measurements, the system detected a maximum thickness of 2120 m in Horseshoe Valley, and snow/firn thickness of 120 m. The collected data allowed the subglacial topography, internal ice structure, and isochronous and snow/ice boundary layers to be detected.

ABBREVIATIONS

CADIC	Centro Austral de Investigaciones Científicas, Ushuaia, Argentina
CECs	Centro de Estudios Científicos, Valdivia, Chile
CEAZA	Centro de Estudios Avanzados en Zonas Aridas, la Serena, Chile
CEQUA	Centro de Estudios del Cuaternario, Fuego–Patagonia y Antártica, Punta Arenas, Chile
CIEP	Centro de Investigación en Ecosistemas de la Patagonia, Coihaique, Chile
COPAS	Centro de Investigación Oceanográfica en el pacífico Sur-Oriental, Concepción, Chile
DGA	Dirección general de Aguas, Ministerio de Obras Públicas, Santiago, Chile
DGF	Departamento de Geofísica, Universidad de Chile, Santiago, Chile
IANIGLA	Instituto Argentino de Nivología, Glaciología y Ciencias Ambientales, Mendoza, Argentina
INACH	Instituto Antártico Chileno, Punta Arenas, Chile
NASA	National Aeronautic and Space Administration, Wallops, USA
PUC	Pontifica Universidad Católica de Chile, Santiago, Chile
RiseU	Rise University, Houston, Texas, USA
SHOA	Servicio Hidrográfico Armada de Chile, Valparaíso, Chile
UACH	Universidad Austral de Chile, Valdivia, Chile
UBC	University of British Columbia, Vancouver, Canada
UCh	Universidad de Chile, Santiago, Chile
UMAG	Universidad de Magallanes, Punta Arenas, Chile
UMAYOR	Universidad Mayor, Santiago, Chile
UW	University of Washington, Seattle, USA

Andrés Rivera

International Glaciological Society

JOURNAL OF GLACIOLOGY

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

L.M. Andreassen, M. Huss, K. Melvold, H. Elvehøy, S.H. Winsvold
Ice-thickness measurements and volume estimates for glaciers in Norway

Robert J. Arthern
Exploring the use of transformation group priors and the method of maximum relative entropy for Bayesian glaciological inversions

Jessica Avva, John M. Kovac, Christian Miki, David Saltzberg, Abigail G. Vieregg
An in situ measurement of the radio-frequency attenuation in ice at Summit Station, Greenland

Martina Barandun, Matthias Huss, Leo Sold, Daniel Farinotti, Erlan Azisov, Nadine Salzmann, Ryskul Usubaliev, Alexandr Merkushkin, Martin Hoelzle
Re-analysis of seasonal mass balance at Abramov Glacier 1968-2014

Perry Bartelt, Cesar Vera Valero, Thomas Feistl, Marc Christen, Yves Bühler, Othmar Buser
Modelling cohesion in snow avalanche flow

Jinlong Chao, Chengyu Liu, Yingjun Xu, Wei Gu, Ying Li, Feng Xie
Multi-angular thermal infrared emission characteristics of Bohai Sea ice based on in situ measurements

Jeff W. Crompton, Gwenn E. Flowers, Dirk Kirste, Birgit Hagedorn, Martin J. Sharp
Clay mineral precipitation and low silica in glacier meltwaters explored through reaction path modelling

Nicolas J. Cullen, Jonathan P. Conway
A 22 month record of surface meteorology and energy balance from the ablation zone of Brewster Glacier, New Zealand

Pierre Dalban Canassy, Claudia Röösli, Fabian Walter
Seasonal variations of glacier seismicity at the tongue of Rhonegletscher (Switzerland) with a focus on basal icequakes

Geoff Evatt, I. David Abrahams, Matthias Heil, Christoph Mayer, Jonathan Kingslake, Sarah L. Mitchell, Andrew C. Fowler, Chris D. Clark
Glacial melt under a porous debris layer

Daniela Festi, Werner Kofler, Edith Bucher, Luca Carturan, Volkmar Mair, Paolo Gabrielli, Klaus Oeggl
A novel pollen-based method to detect seasonality in ice cores: a case study from Ortles glacier, South Tyrol, Italy

Jan-Thomas Fischer, Andreas Kofler, Wolfgang Fellin, Matthias Granig, Karl Kleemayr
Multivariate parameter optimization for computational snow avalanche simulation

Chrystelle Gabbud, Natan Micheletti, Stuart Lane
Lidar measurement of surface melt for a temperate Alpine glacier at the seasonal and hourly scales

Hrafnhildur Hannesdóttir, Guðfinna Aðalgeirsdóttir, Tómas Jóhannesson, Sverrir Guðmundsson, Philippe Crochet, Hálfdán Ágústsson, Finnur Pálsson, Eyjólfur Magnússon, Sven Þ. Sigurðsson, Helgi Björnsson
Downscaled precipitation applied in modelling of mass balance and the evolution of SE-Vatnajökull, Iceland

Eva Huintjes, Niklas Neckel, Volker Hochschild, Christoph Schneider
Surface energy and mass balance at the Purogangri Ice Cap, central Tibetan Plateau, 2001–2011

Angelika Humbert, Daniel Steinhage, Veit Helm, Sebastian Hoerz, Jacqueline Berendt, Elke Leipprand, Julia Christmann, Carolin Plate, Ralf Müller
On the link between surface and basal structures of the Jelbart Ice Shelf, Antarctica

Laura M. Kehrl, Huw J. Horgan, Brian M. Anderson, Ruzica Dadic, Andrew N. Mackintosh
Glacier velocity and water input variability in a maritime environment: Franz Josef Glacier, New Zealand

Inka Koch, Sean Fitzsimons, Denis Samyn, Jean-Louis Tison
Marine ice recycling at the southern McMurdo Ice Shelf, Antarctica

Iwona Kurzyca, Adam Choinski, Joanna Pociask-Karteczka, Agnieszka Lawniczak, Marcin Frankowski
Terms and conditions of high mountain lake ice-cover chemistry (Carpathians, Poland)

Lydie Lescarmontier, Benoît Legrésy, Neal W. Young, Richard Coleman, Laurent Testut, C. Mayet, Pascal Lacroix
Rifting processes and ice-flow modulation observed on the Mertz Glacier

Jun Li, H. Jay Zwally
Response times of ice-sheet surface heights to changes in the rate of Antarctic firn compaction caused by accumulation and temperature variations

Keith W. Nicholls, Hugh F.J. Corr, Craig L. Stewart, Lai Bun Lok, Paul V. Brennan, David G. Vaughan
A ground-based radar for measuring vertical strain rates and time-varying basal melt rates in ice sheets and shelves

Erich Osterberg, Robert L Hawley, Gifford J Wong, Ben Kopec, David Ferris, Jennifer Howley
Coastal ice core record of recent Northwest Greenland temperature and sea-ice concentration

Irina Overeem, Benjamin Hudson, Ethan Welty, Andreas Mikkelsen, Jonathan Bamber, Dorthe Petersen, Adam Lewinter, Bent Hasholt
River inundation suggests ice-sheet runoff retention

Michal Pętlicki, Michal Ciepły, Jacek Jania, Agnieszka Promińska, Christophe Kinnard
Calving of a tidewater glacier driven by melting at the waterline

L. Ruiz, E. Berthier, M. Masiokas, P. Pitte, R. Villalba
First surface velocity maps for glaciers of Monte Tronador, North Patagonian Andes, derived from sequential Pléiades satellite images

Martina Schäfer, Marco Möller, Thomas Zwinger, John C. Moore
Dynamic modelling of future glacier changes: mass balance-elevation feedback in projections for the Vestfonna ice cap, Nordaustlandet/ Svalbard

Simone Schauwecker, Mario Rohrer, Christian Huggel, Anil Kulkarni, Al. Ramanathan, Nadine Salzmann, Markus Stoffel, Ben Brock
Remotely sensed debris thickness mapping of Bara Shigri Glacier, Indian Himalaya

Rolf Sidler
A porosity-based Biot model for acoustic waves in snow

Jakob F. Steiner, Francesca Pellicciotti, Pascal Buri, Evan S. Miles, Walter W. Immerzeel, Tim D. Reid
Modeling ice-cliff backwasting on a debris-covered glacier in the Nepalese Himalaya

Adam Treverrow, Roland Warner, William F. Budd, T.H. Jacka, Jason L. Roberts
Modelled stress distributions at the Dome Summit South borehole, Law Dome, East Antarctica: a comparison of anisotropic ice flow relations

Ward van Pelt, Jack Kohler
Modelling the long-term mass balance and firn evolution of glaciers around Kongsfjorden, Svalbard

Christian Weikusat, Sepp Kipfstuhl, Ilka Weikusat
Raman tomography of natural air hydrates

Michael Zemp, Holger Frey, Isabelle Gärtner-Roer, Samuel U. Nussbaumer, Martin Hoelzle, Frank Paul, Wilfried Haeberli, Florian Denzinger, Andreas P. Ahlstrøm, Brian Anderson, Samjwal Bajracharya, Carlo Baroni, Ludwig N. Braun, Bolívar E. Cáceres, Gino Casassa, Guillermo Cobos, Luzmila R. Dávila, Hugo Delgado Granados, Michael N. Demuth, Lydia Espizua, Andrea Fischer, Koji Fujita, Bogdan Gadek, Ali Ghazanfar, Jon Ove Hagen, Per Holmlund, Neamat Karimi, Zhongqin Li, Mauri Pelto, Pierre Pitte, Victor V. Popovnin, Cesar A. Portocarrero, Rainer Prinz, Chandrashekhar V. Sangewar, Igor Severskiy, Oddur Sigurðsson, Alvaro Soruco, Ryskul Usubaliev, Christian Vincent
Historically unprecedented global glacier decline in the early 21st century

Tong Zhang, Lili Ju, Wei Leng, Stephen Price, Max Gunzburger
Thermomechanically coupled modeling for land-terminating glaciers: a comparison of two-dimensional, first-order and three-dimensional, full Stokes approaches

Yong Zhang, Yukiko Hirabayashi, Qiao Liu, Shiyin Liu
Glacier runoff and its impact in a highly glacierized catchment in the southeastern Tibetan Plateau: past and future trends

H. Jay Zwally, Jun Li, John W. Robbins, Jack L. Saba, Donghui Yi, Anita C. Brenner
Mass gains of the Antarctic ice sheet exceed losses

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*

Jennifer A. King, Grant R. Bigg, Richard Hall
Influence of synoptic atmospheric conditions on movement of individual sea-ice floes in Fram Strait, late summer 2010

Takeshi Tamura, Kay I. Ohshima, Jan L. Lieser, Takenobu Toyota, Kazutaka Tateyama, Daiki Nomura, Kazuki Nakata, Alexander Fraser, Peter Jansen, Kym Newbery, Rob A. Massom, Shuki Ushio
Helicopter-borne observations with portable microwave radiometer in the Southern Ocean and the Sea of Okhotsk

Cunde Xiao, Tingfeng Dou, Sharon B. Sneed, Runxiang Li, Ian Allison
An ice-core record of Antarctic sea-ice extent in the southern Indian Ocean for the past 300 years

Annals 56(69) is now complete

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*

Raymond Le Bris, Frank Paul
Glacier-specific elevation changes in parts of western Alaska

Guisella Gacitúa, José A. Uribe, Ryan Wilson, Thomas Loriaux, Jorge Hernández, Andrés Rivera
50 MHz helicopter-borne radar data for determination of glacier thermal regime in the central Chilean Andes

U.F. Minora, A. Senese, D. Bocchiola, A. Soncini, C. D'agata, R. Ambrosini, C. Mayer, A. Lambrecht, E. Vuillermoz, C. Smiraglia, G. Diolaiuti
A simple model to evaluate ice melt over the ablation area of glaciers in the Central Karakoram National Park, Pakistan

Annals 56(70 is now complete

ANNALS OF GLACIOLOGY 57(71)

The following papers have been selected for publication in Annals of Glaciology *57(70) (thematic issue on Glaciology in High Mountain Asia), edited by Graham Cogley*

Mohd Farooq Azam, Alagappan Ramanathan, Patrick Wagnon, Christian Vincent, Anurag Linda, Etienne Berthier, Parmanand Sharma, Arindan Mandal, Thupstan Angchuk, Virendra Bahadur Singh, P.G. Jose
Meteorological conditions, seasonal and annual mass balances of Chhota Shigri Glacier, western Himalaya, India

Argha Banerjee, Mohd Farooq Azam
Temperature reconstruction from glacier length fluctuations in the Himalaya

Perry A. Bartelt, Othmar Buser, Cesar Vera Valero, Yves Bühler
Configurational energy and the formation of mixed flowing/powder snow and ice avalanches

Anshuman Bhardwaj, Lydia Sam, Shaktiman Singh, Rajesh Kumar
Automated detection and temporal monitoring of crevasses using remote sensing and their implications for glacier dynamics

Pascal Buri, Francesca Pellicciotti, Jakob F. Steiner, Evan S. Miles, Walter W. Immerzeel
A grid-based model of backwasting of supraglacial ice cliffs over debris-covered glaciers

Martin Heynen, Evan Miles, Silvan Ragettli, Pascal Buri, Walter W. Immerzeel, Francesca Pellicciotti
Air temperature variability in a high-elevation Himalayan catchment

Jeevan Kafle, Puskar R. Pokhrel, Khim B. Khattri, Parameshwari Kattel, Bhadra Man Tuladhar, Shiva Prasad Pudasaini
Landslide-generated tsunami and particle transport in mountain lakes and reservoirs

Philip Kraaijenbrink, Sander W. Meijer, Joseph M. Shea, Francesca Pellicciotti, Steven M. de Jong, Walter W. Immerzeel
Seasonal surface velocities of a Himalayan glacier derived by automated correlation of unmanned aerial vehicle imagery

Frank Lehmkuhl, Michael Klinge, Henrik Rother, Daniela Hülle
Distribution and timing of Holocene and late Pleistocene glacier fluctuations in western Mongolia

Andreas Linsbauer, Holger Frey, Wilfried Haeberli, Horst Machguth, Mohd Farooq Azam, Simon Allen
Modelling glacier-bed overdeepenings and possible future lakes for the glaciers in the Himalaya–Karakoram region

Qiao Liu, Wanqin Guo, Yong Nie, Shiyin Liu, Junli Xu
Recent glacier and glacial lake changes and their interactions in the Bugyai Kangri, southeast Tibet

D.M. McClung
Avalanche character and fatalities in the high mountains of Asia

H.C. Nainwal, Argha Banerjee, R. Shankar, Prabhat Semwal, Tushar Sharma
Shrinkage of Satopanth and Bhagirath Kharak Glaciers, India, from 1936 to 2013

Melanie Rankl, Matthias Braun
Glacier elevation and mass changes over the central Karakoram region estimated from TanDEM-X and SRTM/X-SAR digital elevation mdels

Joseph M. Shea, Walter W. Immerzeel
An assessment of basin-scale glaciological and hydrological sensitivities in the Hindu Kush–Himalaya

Marinka Spieß, Christoph Schneider, Fabien Maussion
MODIS-derived interannual variability of the equilibrium-line altitude across the Tibetan Plateau

Sudeep Thakuri, Franco Salerno, Tobias Bolch, Nicolas Guyennon, Gianni Tartari
Factors controlling the accelerated expansion of Imja Lake, Mt Everest region, Nepal

Chaomin Wang, Yaping Liu, Wangbin Zhang, Sungmin Hong, Soon Do Hur, Khanghyun Lee, Shugui Hou
High-resolution atmospheric cadmium record for 1776–2004 AD in a high-altitude ice core from the eastern Tien Shan Mountains, Central Asia

Alāna M. Wilson, Mark W. Williams, Rijan Bhakta Kayastha, Adina E. Racoviteanu
Use of a hydrologic mixing model to examine roles of meltwater, precipitation and groundwater in the Langtang River basin, Nepal

Yulan Zhang, Shichang Kang, Bjorn Grigholm, Yongjun Zhang, Susan Kaspari, Uwe Morgenstern, Jiawen Ren, Dahe Qin, Paul A. Mayewski, Qianggong Zhang, Zhiyuan Cong, Mika Sillanpää, Margit Schwikowski, Feng Chen
Twentieth century warming preserved in a Mt Geladaindong ice core, central Tibetan Plateau

Liyun Zhao, Ran Ding, John C. Moore
The High Mountain Asia glacier contribution to sea-level rise from 2000 to 2050

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

ANNALS OF GLACIOLOGY 57(72)

The following paper has been selected for publication in Annals of Glaciology *57(72) (thematic issue on Hydrology of glaciers and ice sheets), edited by Alexander H. Jarosch and Ian Hewitt*

Douglas Brinkerhoff, Colin R. Meyer, Ed Bueler, Martin Truffer, Timothy Bartholomaus
Inversion of a glacier hydrology model

More papers for Annals 57(72) will be listed in the next issue

New Zealand Branch Annual Workshop

Cass Field Station, New Zealand, 2–4 July 2015

An enthusiastic group of glaciologists, scientists, and students gathered in the snow-clad Canterbury high country for the New Zealand branch of the IGS Snow and Ice Research Group (SIRG) annual workshop.

A great range of research was presented, starting off with some key New Zealand glacier studies. Holly Still (University of Otago) demonstrated the potential of using satellite-derived albedo data for reconstructing mass balance on the Brewster Glacier – a presentation that saw her awarded the prize for top student presentation. Velocity and calving dynamics at Tasman Glacier received significant attention, and the valley-wide implications of glacier retreat at Fox Glacier were highlighted in some rock-fall and geomorphic analysis from researchers at Canterbury University.

Pat Langhorne once again brought a strong sea-ice contingent to the workshop, with student Andrew Pauling presenting some exciting work exploring the interactions between ice shelves and sea ice in the Ross Sea region. Psychedelic images of ice micro-structure accompanied studies exploring ice creep phenomena from Otago's Geology Department, with a good update on their ever-improving electron microscopy capability.

Brian Anderson (Victoria University of Wellington) presented timely research on the benefits and challenges of using remote drone aerial surveys and structure from motion (SfM) to derive high-resolution digital elevation models. It seems that too much data can be as much of a challenge as not enough data! The group listened with interest to efforts to forecast seasonal stream-flow in Chile, pondered the value of n and A, and caught up with significant research activity on the McMurdo Ice Shelf by Gateway Antarctica participants.

The final evening saw a guest presentation from Simon Morris, a snow safety research officer from the nearby Porters Ski Area. Simon provided an overview of planned ski field expansion, and detailed his research mapping snow accumulation and cornice development

The official workshop photo, taken outside the University of Canterbury's Cass Field Centre.

Sandrine and Rachel checking out some layers in a snow core.

Trevor Chinn giving the 'younger generation' a run-down on how to use a Federal Sampler.

in the context of improved avalanche hazard management.

The workshop was rounded off with a life-member presentation to Dr Trevor Chinn for his enthusiastic and sustained contribution to glaciology, and an excursion to Porters Ski Area the next day where the group measured snow depth and snow water equivalent using a variety of techniques. The opportunity to get his hands back on a Federal Snow Sampler brought a smile to Trevor Chinn's face and he gave a polished demonstration of its efficient use to the younger contingent who had never seen such a contraption before!

Overall the workshop was attended by 29 participants from a range of universities and research institutes in New Zealand. The 2015 annual SIRG workshop was hosted by the University of Canterbury's Gateway Antarctica and Geography Department, with sponsorship from NIWA, Antarctica New Zealand and Bivouac. The full proceedings from the workshop can be found at www.sirg.org.nz

Heather Purdie
Photos: Christian Wild

Glaciology in High Mountain Asia

A report on the IGS symposium

Kathmandu, Nepal, 1–6 March 2015

The IGS, in partnership with the International Centre for Integrated Mountain Development (ICIMOD) and other co-sponsors, held a 6-day symposium in Kathmandu, Nepal, beginning on 1 March 2015. This event brought more than 220 participants from 19 countries to a conference venue located near many of the most historic and beautiful parts of Kathmandu. A mere 56 days later, a 7.8 Mw earthquake with an epicentre approximately 80 km northwest of Kathmandu produced a zone of strong ground motion extending east to Kathmandu and beyond, causing tens of thousands of casualties and extensive destruction throughout Nepal, including historic and beautiful parts of Kathmandu visited by IGS delegates only a few weeks before. The present report describes the symposium and the experience of being in Kathmandu when the city and Nepal were at their best, before the unfortunate events brought on by the earthquake. The IGS, ICIMOD and all the co-sponsors express regret that great misfortune has visited a city and a country that had so generously and expertly hosted one of the top symposia on the subject of glaciology in High Mountain Asia held in many years.

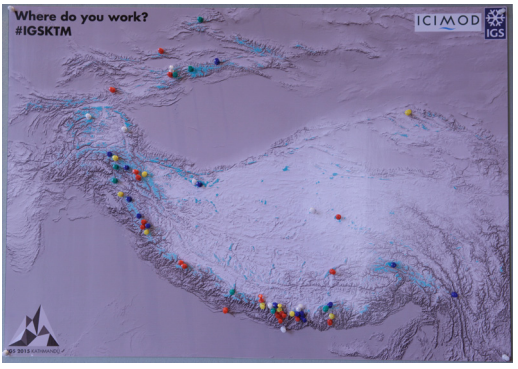
Among the far corners of the world, the glaciology of High Mountain Asia has retained an air of mystery, inaccessibility and *scientia incognita* even while ice and snow science in Earth's polar regions and other mountainous areas has been systematically explored. Possibly, the great unmet need for the penetration of cryospheric science into the realm of High Mountain Asia became most apparent when the Intergovernmental Panel on Climate Change of the United Nations (IPCC) stumbled on the *scientia incognita* of this part of the world (claiming that Himalayan glaciers would largely disappear by 2035) in its fourth assessment report in 2007.

The conception of the IGS Kathmandu symposium began with the realization that the *scientia incognita* of High Mountain Asia glaciology was indeed in the process of being overcome at an ever-accelerating pace since 2007. As the map showing field areas associated with delegates attending the IGS symposium attests, scientia incognito is giving way to scientia explorantur. This became the prime motivator for the symposium.

The local organizing committee, led by Joseph Shea and Michelle Laurie, was given the task of creating a legacy for delegates. With so much data, information and knowledge being brought to the symposium, clearly there was a desire to make sense of what was shared and meet the people behind the research. Where to begin such an important, daunting task?

Well it began at 8:30 a.m. on a Monday morning, as IGS symposia always do, and from the outset it was clear that this symposium in particular was going to be entirely different. The innovative way of organizing the symposium that the organizing committee had gambled on was

The ambiance of the conference venue could best be described as palatial.



A map in the hallway showed where in High Mountain Asia participants were working. Photo Jitendra Bajracharya (ICIMOD).

The sessions were very interactive and required active participation by everyone.

Joe Shea takes time off from organizational duties to explain his poster to an attentive audience. Photo Jitendra Bajracharya (ICIMOD).

about to be put to the test: The spacious and elegant meeting hall of the Yak and Yeti Hotel was filled with round tables inspiring conversation, not the usual rows of chairs facing the speaker's podium and screen. Supplied on each table, besides the freshly cut Nepali flowers provided each day, were various question sheets and fat-tipped markers intended to facilitate communication among the members of each table at regular intervals throughout the day. Immediately following the morning's keynote lecture on glacier change by Andreas Kääb ('Satellite altimetry estimates of early 21st century glacier volume change over the Pamir–Karakoram–Himalaya'), delegates were given 10 minutes to discuss the main messages of the keynote lecture and invent a newspaper or news-service headline that would distil the main message coming from the discussion. The headlines, written on index cards with fat-tipped markers, were then posted on bulletin boards outside the venue for all to admire. The key result, however, was the experience of reflecting on the lecture with both familiar and unfamiliar delegates seated around each of the tables. These headlines set the scene for the day's learning.

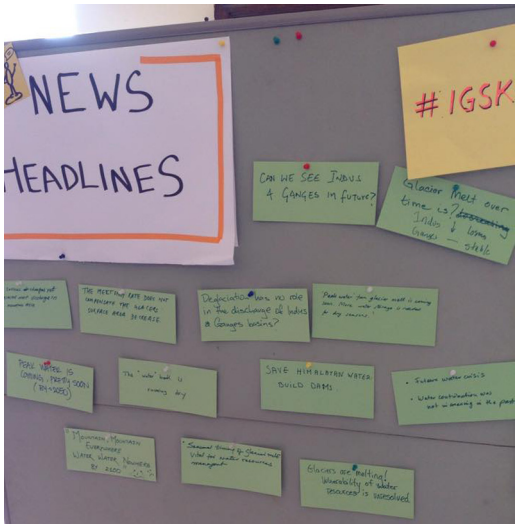
This unconventional activity added to the morning's programme following each of the four keynote lectures delivered though the week (by Kääb, Jacobi, Marzeion and Zhao) was instigated by the local organizing committee led by Joe Shea and by Michelle Laurie, a specialist in facilitating large conferences and practitioner of the principles advocated by the 'Open Space' meeting philosophy (http://openspaceworld.org/wp2/). Throughout the sessions, formal time was scheduled with activities that involved the delegates in something more than just sitting sleepily listening to oral presentations or wandering through impersonal crowds in poster halls. Each oral session was followed by 10 minutes of built-in discussion time, when discussion within groups of five to ten delegates sitting at each of the 25 or so round tables in the lecture hall was focussed on one of two generic questions: 'What are the key points learned from the session?' and 'What questions remain to be answered (and how) about the topic of each session?' The discussion summaries, written up with fat-tipped marker (to keep answers succinct) at each table, were later summarized by a team of rapporteurs (aka Session Chairs), who presented an overview of the session at the start of the next day. The full synthesis was later shared as part of further outreach from the organizers to delegates and the glaciology community.

Poster sessions also benefited from Michelle Laurie's conference facilitation expertise. Each of the two poster sessions had fun 'projects' associated with them that would break the ice between poster presenter, poster viewer and fellow delegates. At one poster session, delegates were

At the beginning of each day, session chairs from the previous day gave a report on what had transpired during their sessions.

The poster sessions generated a lot of lively discussion. Photo Jitendra Bajracharya (ICIMOD).

Farjana Birajdar and friends prepare her poster for display. Photo Jitendra Bajracharya (ICIMOD).



After each session people were given the task of coming up with catchy headlines encapsulating its key points.

On Wednesday morning participants could devise their own sessions. Here, a group of them are logging their suggestions on the board.

Once the sessions were established, group discussion could begin.

One of the Wednesday morning sessions was on the responsibilities of Scientific Editors. It attracted the participation of the IGS Chief Editor, Jo Jacka, and of Graham Cogley, Chief Editor of the thematic *Annals* issue on Glaciology in High Mountain Asia.

Midpoint break for the midweek hikers in the Nagarjun Forest: time for rest and some scenic photography. Photo Arttu Jutila

given a list of 'scavenger hunt' tasks that required signatures of participants at the symposium who represented 'solutions' to the riddles or questions. At the other poster session, poster viewers were issued with 'passports' that could be 'stamped' by poster presenters when the presenter felt that a major point about their poster had been successfully communicated to the viewer. At the end of the symposium, awards were given to the delegates who had best solved the riddles of the poster scavenger hunt and had amassed the most stamps in their passport.

Possibly the most avant-garde use of Open Space principles was on the middle day of the symposium, when the normal pre-designed agenda was jettisoned to allow the delegates to create an agenda 'on the spot' by proposing themes that focussed on the future of glaciological

The Secretary General employed a novel method of directing the midweek excursion to Bhaktapur.

The market square in Bhaktapur. A few weeks later the earthquake reduced this whole area to rubble.

science in High Nountain Asia. This was an opportunity for people who came from all over the world to meet to discuss topics that were truly of interest to them (but not on the formal agenda). Index cards scattered on the floor in the centre of the circle formed by delegates sitting in the round could be picked up and used to propose a session theme. These cards were then organized into two sets of breakout sessions (eight breakouts each) that were conducted through the morning. Paramount in the success of the breakout sessions were the four principles of Open Space: (1) Whoever comes is the right person; (2) Whenever it starts is the right time; (3) When its over, its over; and (4) Whatever happens is the only thing that could happen. These principles were tempered by the 'law of two feet': 'If at any time during our time together you find yourself in a situation where you are neither learning nor contributing, use your two feet and go someplace else'.

The vibrancy and newness of the symposium format was second only to the noteworthy scientific content exchanged throughout the week's sessions. Articles appearing in the popular press (e.g. Qiu (2015) and media coverage listed in http://www.icimod.org/?q=17276) pronounce the symposium a success in 'narrowing the knowledge gap on glaciers of High Mountain Asia'. Of particular note was that research presented at the symposium clarified aspects of Asian glaciology that had previously been poorly understood. These aspects included the overview of changing glacier length and volume in a number of key areas including the Karakoram, which is commonly referred to as the 'Karakoram anomaly'; the extent to which glacier ice contributes to river water resources in various basins and over various fetches of agricultural significance; and the multifaceted hazards posed by glaciered terrain, especially where there are possibilities of glacier lake outburst floods.

The beginning of the banquet was heralded by a gorgeous sunset.. Photo Arttu Jutila.

Perhaps the most endearing experience of the symposium, particularly in light of what has happened since the symposium concluded, was the midweek excursions by the delegates to various sites within and surrounding the Kathmandu valley. Two excursions were enjoyed by various groups of delegates. Those interested in hiking and beautiful natural views visited the Nagarjun Forest, where they could see the mountains surrounding Kathmandu and could look down on the city below. Those interested in Nepal's ancient and venerable culture took a walking tour of Bhaktapur, a 15th century city filled with cultural treasures, temples, pagodas and stupas. As with the hike through the Nagarjun Forest, participants in this excursion enjoyed

At the banquet Andrew Mackintosh (Secretary General of IACS) joined the IGS President and Secretary General to present one of the two awards for the best student presentation to Philip Kraaijenbrink. Martina Barendun was the other winner. Photo Michael Bründl.

The President thanked all those who had helped behind the scenes to make the symposium such a success. Photo Michael Bründl.

copious free time to enjoy the Nepali ambiance, take memorable photographs and shop.

Following the symposium, some delegates remained in Nepal for additional pre-arranged excursions or to conduct research in the high mountains looming over Kathmandu. One group spent eight days trekking into one of the premier regions of Nepal to view what some consider to be the world's most spectacular high-mountain scenery, including the Annapurna massif, Machhapuchhre (Fishtail) and Dhaulagiri. A second, smaller group spent seven days on a less strenuous visit to two of Nepal's favorite tourist destinations: Pokhara, the city at the foot of the Annapurna range, and Chitwan National Park, in the Terai region, known for its wildlife, including one-horned rhinoceros and gharial crocodiles. Reports of these post-symposium excursions are included below.

Overall, the symposium held at Kathmandu in March 2015 is remembered for two qualities: it fostered scientific exchange in a place of spectacular natural beauty and rich cultural heritage, and it introduced many visitors to Nepal to the warm hospitality and generosity of the Nepali people. For many delegates, the experience of attending the symposium and seeing Kathmandu at its best makes the recent tragedy that much more heartrending.

The IGS wishes to thank the local organizing committee, Joseph Shea (Chair), Lochan Devkota, Rijan Kayastha, Pradeep Mool, Arun Shrestha, Dorothea Stumm, Prerna Thapa and Patrick Wagnon, for their perfect execution of the symposium arrangements. Thanks are also due to Michelle Laurie for facilitating some of the very new methods and activities that enhanced the quality of communication throughout the symposium and are also extended to the people who worked behind the scenes to ensure the success of each day's activity.

Doug MacAyeal

A post-symposium excursion to Pokhara and the Terai

Following the 2015 IGS symposium in Kathmandu, a small group of delegates and accompanying people explored two of Nepal's most interesting sites: the foothills of the Annapurna massif near Nepal's second largest city, Pokhara, and the Royal Chitwan National Park of Nepal, a UNESCO World Heritage Site.

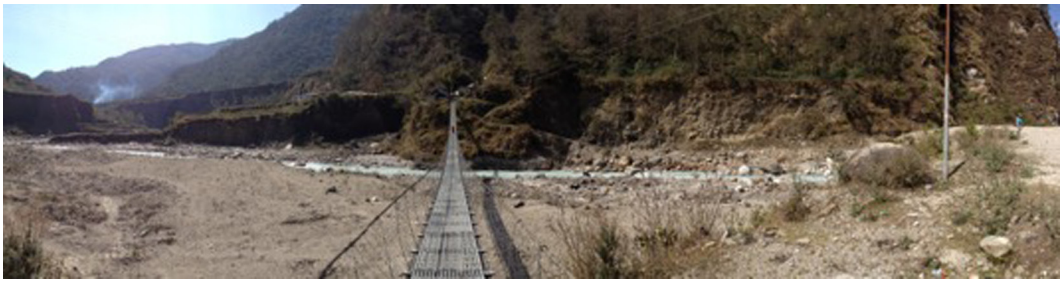
Pokhara, besides being a city with a less hurried feel than Kathmandu, is set beside a beautiful lake that reflects the extraordinary high relief of the Annapurnas and Machhapuchhre ('fish tail'). The city hosts various museums, including the very extensive International Mountain Museum, religious sites and temples, including a World Peace Pagoda created by Nichidatsu Fujii, and a delightful range of enjoyable tourist activities ranging from paragliding to watching the sun rise over the Annapurnas.

As part of the excursion to Pokhara, a one-day field trip was organized to sites along the Seti River (which flows through Pokhara from the foot of Annapurna IV), where a disastrous flash flood occurred in 2012. This flash flood caused many casualties and was originally thought to be a form of glacial lake outburst flood. However, later research revealed that the flood was due to a landslide-created ephemeral lake within a gorge that is relatively hard to monitor for such hazards. As a measure of the progress in making science more useful to people, the Seti River flood of 2012 was used as a case model to assist in the monitoring of similar ephemeral landslide-origin lakes created in the aftermath of the 25 April earthquake.

Chitwan National Park is part of the Terai, low-lying jungle on the border of Nepal and India. The excursion travelled to Chitwan from Pokhara by

On the field trip up the Seti River with Kagendra Poudel (second from right), our local guide from Kathmandu University.

Chief Editor Jo Jacka identifies a rhino in the distance.



Exploring the Seti River near Kharapani where casualties occurred in 2012. The sudden flood swept people off the suspension bridge and from a hot spring near the river bank. Houses were once located on the terrace in the foreground.

road, and this gave the group a small taste of the challenges of road travel experienced by the relief effort only a month and a half later. Although the journey was time-consuming (6 hours to cover about 150 km), it was comfortable and ended at a hotel on the outskirts of the park that was renowned for arranging experiences and treks into the park. Over the span of two days, we enjoyed an elephant trek to see the famous Asian rhinos as well as a more extensive jeep trek giving views of water buffalo, gharial crocodiles, macaques, monitor lizards and peacocks displaying their plumage (but no Bengal tigers…).

Combined with the week-long symposium in Kathmandu and the mid-week excursions taken there, the post-symposium visit to Pokhara and Chitwan provided an extraordinary opportunity to understand the culture, history and natural history of Nepal.

Doug MacAyeal

Pokhara potters believe in attracting passing trade by having their entire stock on display...

... and continually adding to it.

The Chief Editor contends with a hostile reviewer at the International Mountain Museum in Pokhara.

Both Kathmandu and Pokhara were fully wired up for ultrafast broadband.

Through the hills and up to the glaciers – post-conference excursion to the Annapurna Sanctuary

When signing up for the IGS conference in Kathmandu, most of the over 250 participants reportedly thought: 'An excursion to the Annapurna massif! Sounds awesome. But no way! Me, an experienced glaciologist and mountaineer, walking in line with fifty others, possibly modellers who have never seen a mountain before? I'd rather book my own trek.' And so it happened that on Sunday 8 March 2015 a group of only nine scientists from four different countries started the post-symposium excursion, an eight-day trek in one of the premier trekking regions of Nepal to the Annapurna Sanctuary, organized by the trekking organization Glacier Safari Treks. For most of us it was the first visit to the Himalayas – and we were all delighted to find our nightmares of a mass hike turn into a fantastic trek with a small group of experienced and enthusiastic mountaineers!

The first hurdle: getting to Pokhara

It takes some time and effort to visit those magnificent mountains. To start with, we had to get from Kathmandu to Pokhara. Instead of picking up everyone at their individual hotels, our efficient trekking organization ordered us tired folks to show up at 7 am at the conference hotel, so we would be out of reach of the city before morning rush hour. Our guide, Nawang Sherpa, saw to it that all our luggage was attached safely on the roof of our exclusive tourist van, and we set off after a mere 30 minutes delay – to then first crawl into the very heart of Kathmandu, at a walking pace through the narrow alleys, to pick up the driver's mother, who had some business to do in Pokhara. By the time the group was complete, Kathmandu's infamous traffic was doing an excellent job at what it is known for, and we had ample time to take pictures of what was going on in the streets while poking along until we finally left Kathmandu valley. Along the way, Nawang made sure we had frequent 'pee-pee breaks', as he cheerfully called them, and made the driver stop at a roadside restaurant where we got treated to our first dal bhat tarkari for lunch. Dal bhat is the Nepalese national dish and consists of rice, lentils and two kinds of vegetables. Authentic Nepalese food, we were delighted, and it was delicious! But there was maybe also the slight worry – were we going to eat this for breakfast, lunch and dinner for the next eight days in a row…?

Dal bhat tarkari – for many of us the daily dinner, with dal = lentil soup, bhat = steamed rice and tarkari = vegetables.

Kathmandu and Pokhara are only 200 km apart, but it takes a full day to do the trip. After a six-hour drive on a bumpy, winding road, where

Our group in front of Machhapuchhre (6997 m.a.s.l.) at Australian Camp. From left to right: Felix Matt, Richard Hayes, Ellen Viste, Markus Engelhardt, Frank Lehmkuhl, Carola Lehmkuhl, Désirée Treichler, James Douglas, Louise Parry.

Farms within terraced fields in Tolka.

Markus trying out the Nepalese carrying system.

we got to experience an impressive variety of manoeuvres made possible by the apparently rather relaxed Nepalese traffic rules, and the queasy stomach that came with them, we reached the second largest city in Nepal. There we relaxed for the rest of the day. We couldn't help thinking: If merely the bus ride was exhausting, both physically and mentally, how were we going to tackle the walking that would follow?

Through forested hills with scenic views

On the morning of the second day we woke up to blue sky and, from the hotel balcony and through palm trees, a tiny glimpse of massive, snow-covered peaks in the distance! But they were far away, and still seemed so after the short bus ride to Kande, at 1770 m, where we were going to join the vast network of hiking trails in the hills south of the Annapurna massif. It did not look like Himalaya mountains much, there: neither blue, crevassed glaciers nor brutal rock faces in sight, only forested hills and here and there a farm with terraced fields and cows grazing lazily in the morning sun. In Kande we met our second guide, Dawa Sherpa, our cook, Basang Sherpa, and our five porters – all at least a head shorter and maybe half the weight of the average of us Westerners. The porters each carried two of our big bags, in addition to their own luggage, of course. Taking into account the weight limit of 13 kg per tourist, that adds up to some 30 kg of bags strapped together into a bulky bundle, resting loosely on their backs while held in place by the traditional strap around the forehead only. Naturally, most of them found wearing slippers would do just fine for the job (they did have better shoes in their little packs, as we learned later). While happy to prance about light-footedly, we felt slightly guilty that these short, skinny men should carry our loads when we could have done so perfectly well ourselves. After all, the wide path didn't look really difficult.

But already the first kilometre and maybe 500 stair-steps made us realize that this was not going to be a walk in the park: the trail was steep, our legs not prepared for the Nepalese stairs at all, and the sun merciless at nine in the morning. Thankfully, after a week of sitting in the ballroom of the Yak and Yeti Hotel staring at slide after slide of pictures of scenic mountain landscapes, all we wanted was to be outside, however strenuous it might be, and eagerly awaited what Nawang promised us for the first day: spectacular views of the Annapurna massif and Machhapuchhre (6997 m, also known as Mount Fishtail), with its distinct silhouette.

Machhapuchhre in the evening sun, from the north…

…and Machhapuchhre from the south.

And already after the first hour of stairs, on reaching the Australian Camp, this promise came true: Under a cloudless sky, we saw the skyline of the mountain range that would take us three full days to reach. And we were sure that if Machhapuchhre were in the Alps, it would feature on every single Swiss chocolate bar. It surely starred in every second picture we took. We could probably create a 3-D photogrammetric model of that mountain after this excursion.

Getting into routines

Every day around 11 we stopped at a lodge where we were served – no, not dal bhat, but carbohydrate-rich, hot lunches consisting of rice, potatoes, fried bread and some veggies; or potatoes, fried noodles, bread, and a little salad; or rice, fried potatoes, and noodles – you get the pattern. Of course there were always second helpings, too. Luckily, we had five strong men who helped the four ladies finish their huge plates by eating triple portions!

Louise and Ellen enjoying afternoon tea with mountain views!

Breakfast in the ‘dining hall’ of our lodge.

The afternoon sections were usually a bit shorter and we reached the lodges where we stayed for the night just in time for tea and biscuits around 2–3 pm. That gave us enough time to recover, stroll around and look in fascination at the people in the villages performing just ordinary every-day tasks, or take yet another picture of Machhapuchhre from a slightly different angle.

Playing cards was also a favourite pastime. Most popular, with the top numbers of spectators among our porters and guides, was the game ‘slap’ – perfectly suited to scientists, it involves zero strategy but only luck and a quick hand. We must have been just as entertaining as a reality TV show.

On the succeeding mornings, we got into a kind of a routine: get up with the sun, hot breakfast of our choice at 6:30, and departure at 7:00! Sounds early? That was what we thought, too, on the first day – but after we got our third hot meal of the day around six in the evening, we managed to stay up for a mere hour in the dim light of two naked lightbulbs before everyone was yawning and retreated to bed.

As far as the hiking went too, we followed the same pattern for the first three days: Up a hill (stairs), down again on the other side (stairs, too), across the river on a rope bridge, and then stairs up again on the other side. On the way, we passed numerous little farms with their terraced fields and friendly inhabitants, villages with lodges featuring attractive names like ‘Top View Guest House’, ‘Mountain View Guest House’, ‘Excellent View Guest House’, ’Super View Guest House’, ‘Heaven View Guest House’– and maybe one or the other ‘Green View‘, situated definitely too deep down in a valley to claim stunning mountain views.

River crossing – on a wooden bridge, for once. Markus can't wait for the uphill on the other side!

Up the valley and into the heart of the Sanctuary

The tracks are frequently used, not only by tourists. All local traffic and transport beyond Kimche and Landruk travels via the same paths, on the backs of mules and humans. We met workers carrying anything from large bundles of greens for the cows and baskets filled with cooking pots to long wooden beams used for construction purposes. The steel cables of which the rope bridges are built were carried there by human chains, too. In Deurali, at 3230 m, there is a coffee place with a huge commercial coffee machine – brought there on someone's back. Although whether that paid off we cannot say; we gave up waiting for a cappuccino when the coffee machine still hadn't finished preheating after 15 minutes. A highlight on the way up was the hot spring at Jhinu Danda. Tough glaciologists as we are, we had to take the mandatory dip in the icy Modi Khola, the river that drains the glaciated heart of the Annapurna massif. But that's no problem if there are hot springs just 5 m from the river! Delighted, after a long morning of walking, we soaked in the beautifully carved rock pools filled with 39°C warm water.

Too bad that the clean and relaxed feeling soon wore off when we proceeded from the spa lunch break with a 600 m stair climb to Chomrong, where we spent the night in our favourite lodge ('Excellent View Top Lodge') of the trek.

Chomrong is the last village on the way to Annapurna Base Camp. From there the trail starts climbing steadily, first through blooming

Annapurna South (7220 m.a.s.l.) in the early morning sun.

Louise reaches the top of 600m of brutal stairs.

'Excellent View Top Lodge' – our favourite!

March is the time when rhododendrons bloom.

red rhododendron, followed by huge bamboo forest that gradually turned into a juicy green, wet jungle of oaks festooned with epiphytes, and a dense understorey.

Day four of our hike was by far the most strenuous: From Himalaya Hotel (despite the name the shabbiest lodge of our trek) at 2900 m, we climbed all the way to the Machhapuchhre Base Camp at 3800 m – before lunch. Not only did the elevation kick in that high up, we also passed the snow line, and the track became steep and increasingly exposed. Large amounts of precipitation just a week prior to our trek had forced many hikers we met on the way up to turn

Markus blending in perfectly with the wet forest at about 2600 m.a.s.l.

Felix crossing the huge deposit of a recent wet avalanche.

around. When we got to Deurali, the trail was just passable again – but we still had to expect avalanches any time after 10 am in the now very steep and narrow valley.

Progress was slow, and we crossed several massive avalanche deposits before we finally arrived where the valley bends to the left, and the heart of the Sanctuary appeared in front of our eyes! The panoramic view from Machhapuchhre Base Camp is stunning, an amphitheatre of rough mountains with giant rock faces that extend another 3000–4000 m in elevation above the camp in all directions. By the way, the 'base camp' is just there for tourist purposes – the summit of Machhapuchhre has reportedly never been conquered. A British team nearly succeeded in 1957 but had to retreat a hundred metres or

Finally we reached Machhapuchhre Base Camp, at 3700 m.a.s.l.! Extensive field studies showed that we had about 10 minutes before getting sunburned. In the background Annapurna South.

Désirée posing in front of Annapurna I (8091 m.a.s.l.), with Annapurna South Glacier flowing from the mountain's south face.

so short of the summit. Not long thereafter, the mountain was declared sacred and closed to mountaineering expeditions.

So there we sat, doing exactly what tourists are supposed to in that fake base camp: admiring the pyramid-shaped mountain while enjoying a sunbath at 3700 m. But the strenuous day was not over yet. The sunny weather was about to change. Some of our group suggested that we cut the trip short and start our return the following day, without staying another night at Annapurna Base Camp (4130 m) – not least as a more knee-friendly alternative that would split the downhill trek into more but shorter days. Consequently, we decided to venture to Annapurna Base Camp the very same afternoon. That's yet another 400 m higher, and not everyone was equally excited by the prospect of a hike in the now slushy snow, topped off by a slight headache from high elevation and thin air.

Basang, our cook, leading the way back down for Frank and Carola – across the icy, refrozen snow in the early morning hours.

Frank and Basang – heavy backpack, or just sad to leave Annapurna Sanctuary?

But oh, it was absolutely worth the effort! The panorama only ever got more exciting, and when Annapurna I finally came into sight, we even forgot to take pictures of Machhapuchhre. The south face of Annapurna I, at 8091 m the lowest of the Earth's 14 eight-thousanders, is one of the most difficult climbs on Earth. Our guide Nawang, who has already stood twice on the summit of Mount Everest, said Annapurna was a killer mountain that he would never attempt to climb. Looking at the steep, beautiful conglomerate of rock and ice across its heavily crevassed and debris-covered glacier, we could nevertheless understand why there are still people trying: the sight is simply breathtaking.

Back to civilization – what remains?

We could easily have stayed for days at the Annapurna Base Camp, simply staring at these stunning mountains in awe and peaceful happiness. But we had to head back down – and as predicted by Nawang, clouds came up. By the time we reached the oak forests, rain was pouring down, and continued to do so all afternoon and for most of the succeeding days. Until Chomrong the way down was the same as up, but then we ventured into a different route on the western side of the valley. Our hiking days were now considerably shorter than on the way up, a fact our knees were grateful for. On day 7 of our trek, we ended up in Ghandruk, the largest village in the valley. Despite its rural appeal, we found the two-storey buildings strangely civilized after the pureness of the landscapes of the previous days.

In Ghandruk, we had the opportunity to learn more about Nepalese culture. The mothers committee – Nepalese have committees for everything, we learned – gave a performance of

A mule on the way to Ghandruk.

Thank you, Nepal, for an amazing post-conference excursion!

local songs and dances in traditional costumes on the patio of our lodge. While most of us tourists were too embarrassed to join the dancing, our guide was the star of the night! A visit to the temple and the local museum, with its neat collection of everyday items, gave us some insight in how people used to live, and still do, in this scenic but demanding mountain landscape.

Clouds coming up over the Annapurna massif.

After the impressions of the past week, and with what we learned about Nawang and his life after we got to know each other better, we learned to admire the Nepalese people. Most of them don't have much – and the ones we met, living at the tourist hotspots, still have more than others who are not so fortunate. And yet they are so friendly, and caring. There is a great sense of community. Even though we were just tourists and did not have closer relations to any Nepalese, we felt strangely accepted and included, just because we were there, too, in their fantastic, scenic mountain country.

Therefore, the news of the 25 April earthquake hit extra hard. It did not matter that everyone was fully aware of the risk, even waiting for the disaster to strike, and it did not help that we had been discussing this over a beer at the conference in Kathmandu. Having been there just a few weeks before the catastrophe, driven through the narrow streets of Thamel that are now filled with piles of rubble, and laughed with the friendly locals, we feel the deepest sympathy for this stunning country and its inhabitants. We would like not only to thank our seven fellow glaciologists, our guides and porters for an amazing trek, but also to thank everyone who is contributing to help Nepal get over the damage the earthquake caused. And one thing is for sure: this was not the last time we shall visit the Himalayas!

Désirée Treichler and Markus Engelhardt

Annapurna Sanctuary – the breath-taking panorama from Annapurna Base Camp, 4130 m.a.s.l.

News

International Glaciological Society seeks a new Chief Editor

The International Glaciological Society (IGS) seeks a new Chief Editor (CE) to oversee its publications, including *Journal of Glaciology* and *Annals of Glaciology*. Founded in 1947, the *Journal of Glaciology* has a long history of service to, and engagement with, the cryospheric research community. Dr Jo Jacka, who has led the *Journal* and *Annals* through considerable growth over the last 11 years, intends to retire from this position in 2016. The IGS thus seeks a new CE to manage the Society's editorial needs during its next phase of development. The CE chairs the Editorial Board of the IGS, comprising the CE, three Associate CEs and a team of Scientific Editors (SEs) who manage the review process in their respective disciplinary areas. The CE and Associate CEs will through their combined expertise represent the major groupings: Physical Sciences, Geosciences, Life Sciences and Paleoclimate.

The CE and Associate CEs are appointed by the IGS Council and work closely with the Secretary General. SEs are appointed by the IGS Council, in consultation with the CE team. The Society has traditionally encouraged a high level of interaction between its CE and authorship/readership by supporting CE travel to IGS symposia.

The CE appointment will be made for an initial service term of three years, following a transitional period with Dr Jacka. The role carries an estimated time burden of one day per week. Interested individuals are invited to submit a letter of interest and CV to Publication Committee Chair Dr Christina Hulbe by 1 January 2016. The letter of interest, not longer than two pages, may briefly touch on editorial experience, past Society interaction, publishing philosophy and/or motivation for taking on a CE role.

Overview of key CE needs:

- Ensuring the Society continues to publish high-quality research papers on ice and snow research. Together, the CE team is responsible for assigning individual SEs to papers submitted to the Journal, and is responsible for final publication approval in both the *Journal*, as well as *Annals*, although the latter typically has an issue-specific editorial committee. This requires a commitment to the Society's scholarly values and standards.
- Implementing IGS policies concerning the scholarly review process, consultation with the SG and the IGS Council, and reporting on publication matters, including SE recommendations and publication statistics, to Council at least annually. The transition to Open Access and paperless publishing will be an important focus for the new CE, and he or she will be asked to demonstrate leadership in adopting the new framework and procedures.
- Working collaboratively with representatives of Cambridge University Press, the publisher of the *Journal* and *Annals*, to ensure smooth functioning of the submission, review and publication cycle; and to promote forward-looking opportunities for the IGS in this context.

Availability for interaction with Society members and authors, especially at IGS Symposia. Outreach to the broader cryospheric research community regarding the *Journal* and *Annals*, in collaboration with the Secretary General. It is anticipated that social media will become a more important avenue for this activity in the years ahead.

International Glaciological Society seeks three new Associate Chief Editors

The International Glaciological Society (IGS) seeks to appoint three new Associate Chief Editors to oversee its publications, including *Journal of Glaciology* and *Annals of Glaciology*, in collaboration with its CE. Founded in 1947, the *Journal of Glaciology* has a long history of service to, and engagement with, the cryospheric research community. The 2016 change to a fully Open Access publishing model marks a new era for the Society and the IGS seeks to build a strong Chief Editorial team who will work closely with the Secretary General, Council and Publications Committee to support the new publishing model.

The IGS Editorial Board comprises a Chief and three Associate Chief Editors, and a team of Scientific Editors (SEs) who manage the review process in their respective disciplinary areas. The CE and Associate CEs together represent the major groupings: Physical Sciences, Geosciences, Life Sciences and Paleoclimate. The CE and Associate CEs are appointed by the IGS Council and work closely with the Secretary General. SEs are appointed by the IGS Council, in consultation with the CE team.

The Associate CE appointments will be made for an initial service term of three years. The role carries an estimated time burden of one-half day per week. Interested individuals are invited to submit a letter of interest and CV to Publication Committee Chair Dr Christina Hulbe by 1 January 2016. The letter of interest, not longer than two pages, may briefly touch on editorial experience, past Society interaction, publishing philosophy and/or motivation.

Overview of key Associate CE needs:

- Ensuring the Society continues to publish high-quality research papers on ice and snow research. Together, the CE team is responsible for assigning individual SEs to papers submitted to the Journal, and is responsible for final publication approval in both the *Journal*, as well as *Annals*, although the latter typically has an issue-specific editorial committee. This requires a commitment to the Society's scholarly values and standards.
- The transition to Open Access and paperless publishing will be an important focus for the new CE team. Leadership adopting the new framework and procedures is essential.
- Availability for interaction with Society members and authors, especially at IGS Symposia. Outreach to the broader cryospheric research community regarding the Journal and Annals, in collaboration with the Secretary General. It is anticipated that social media will become a more important avenue for this activity in the years ahead.

Glaciological diary

** IGS sponsored * IGS co-sponsored

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
Jouvence, 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 & Carbosphere
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
Karthaus 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 [J.Oerlemans@uu.nl]
Website: http://www.projects.science.uu.nl/iceclimate/karthaus/

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

24–26 September 2015
Mathematics of Sea Ice Conference
Vancouver, British Columbia, Canada
Website: https://www.pims.math.ca/scientific-event/150924-cmsi

16–17 October 2015
NorthWest Glaciologists Meeting
Portland, Oregon, USA
Contact: Andrew Fountain [andrew@pdx.edu]

26–28 October 2015
Workshop: Halogen chemistry over the sea ice in the Antarctic winter and spring
Grenoble, France
Website: http://www-liphy.ujf-grenoble.fr/halogen-chemistry-antarctica/
Contact: Guillaume Méjean [guillaume.mejean@ujf-grenoble.fr]

29–31 October 2015
IGS Nordic Branch Meeting
Copenhagen, Denmark
The meeting is co-hosted by the Geological Survey of Denmark and Greenland (GEUS) and the Niels Bohr Institute, University of Copenhagen (NBI)
Contact: Christine Hvidberg [ch@nbi.ku.dk]; Andreas Ahlstrøm [apa@geus.dk]
Website: https://sites.google.com/site/igsnordicbranch2015/

6–8 November 2015
9th Graduate Climate Conference
Woods Hole, Massachusetts, USA
Website: http://www.graduateclimateconference.com/

10–11 November 2015
FRAM Science Days: Multi-stressors in the Arctic Marine Ecosystem
Fram Centre, Tromsø, Norway
Website: http://mform.imr.no/view.php?id=42242

10–13 November 2015
1st Central European Polar Meeting
Vienna, Austria
Contact: Marion Rothmüller [cepm2015@polarresearch.at]
Website: http://www.polarresearch.at/conference

16–19 November 2015
Sixth Symposium on Polar Science
Tokyo, Japan
Website: http://www.nipr.ac.jp/symposium2015/e/

2016

13–15 January 2016
32nd Nordic Geological Winter Meeting
Helsinki, Finland
Session: Arctic Research. Conveners: Anne Lehtinen; Jon Engström [jon.engstrom@gtk.fi]
Website: http://www.geologinenseura.fi/winter_meeting/registration.php

14–20 February 2016
2nd Snow Science Winter School
Preda and Davos, Switzerland
Website: http://www.slf.ch/dienstleistungen/events/snowschool/index_DE

9–13 May 2016
European Space Agency Earth Observation and Cryosphere Science conference 2016
hosted during the ESA Living Planet Symposium 2016
Prague, Czech Republic
Website: http://lps16.esa.int/

9–13 May 2016
4th CryoSat User Workshop
hosted during the ESA Living Planet Symposium 2016
Prague, Czech Republic
Website: https://earth.esa.int/web/guest/missions/esa-operational-eo-missions/cryosat/news/-/article/cryosat-4th-user-workshop

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

10–15 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

12–17 February, 2017
****International Symposium on the Southern Cryosphere: Climate Drivers and Global Connections**
Wellington, New Zealand
Contact: Secretary General, International Glaciological Society

August/September 2017
****International Symposium on Polar Ice, Polar Climate and Polar Change: Remote sensing advances in understanding the cryosphere**
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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