Conference and Workshop

Climate Impacts on Glaciers and Biosphere in Fuego-Patagonia

July 14th to July 19th 2017, Berlin

Humboldt-Universität zu Berlin
Geographisches Institut
Klimageographie

The GABY-VASA project, a joint project of University of Magallanes (Punta Arenas), the Instituto Antártico Chileno (INACH, Chile), and in Germany the Humboldt-Universität zu Berlin, the Universität Erlangen-Nürnberg and RWTH Aachen University on dendrochronology, climatology and glaciology in Southern Patagonia and the Cordillera Darwin provides the floor for the international Conference and Workshop

'Climate Impacts on Glaciers and Biosphere in Fuego-Patagonia'

July 14th to July 19th 2017, at Humboldt-Universität zu Berlin. GABY-VASA stands for

„responses of **G**l**A**ciers, **B**iosphere and h**Y**drology to climate **VA**riability and climate change across the **S**outhern **A**ndes"

GABY-VASA is a Chilean-German cooperation project jointly funded by the Comisión Nacional de Investigación Científica y Tecnológica (Conicyt) in Chile and the Bundesministerium für Bildung und Forschung (BMBF), the Federal Ministry of Education and Research, Germany.

On Monday, 17th and Tuesday, 18th July, 2017, an open science meeting is held with sessions on dendro-ecology, climate variability and climate history, climate change, biological responses to climate forcing, glaciology, glacier change, glacio-isotasy and related topics in earth sciences.

The regional focus of this conference is Patagonia, Tierra del Fuego and adjacent islands, the sub-Antarctic islands and the Antarctic Peninsula.

On Wednesday, July 19th, 2017, GABY-VASA is hosting an internal workshop of the GABY-VASA project group with participants from Chile and Germany and additional participants from outside.

The official program starts with a reception on Friday, July 14th in the evening with a get-together. It continues with an organized visiting program in Berlin and Potsdam on the weekend July 15th/16th, 2017 (see following pages).

Scientific Committee
Matthias Braun, Univ. Erlangen-Nürnberg
Gino Casassa, Univ. Magallanes, Punta Arenas
Ricardo Jaña, INACH, Punta Arenas
Juan Carlos Aravena, Univ. Magallanes, Punta Arenas
Christoph Schneider, Humboldt-Universität zu Berlin

Local Organising Committee
Christoph Schneider, Humboldt-Universität zu Berlin
David Steger, Humboldt-Universität zu Berlin
Mahdi Motagh, Geoforschungszentrum Potsdam

Photo on front page: Christoph Schneider, 2015

We gratefully acknowledge the financial and institutional support from

- **Federal Ministry of Education and Research, Germany (BMBF)**

- **Comisión Nacional de Investigación Científica y Tecnológica (Conicyt)**

- **International Glaciological Society (IGS)**

- **The Research Network for Geosciences in Berlin and Potsdam (Geo.X)**

Conference 'Climate Impacts on Glaciers and Biosphere in Fuego-Patagonia'

Information on the by-programme Friday, July 14th – Sunday, July 16th, 2017

On Friday 14th July, from 6 pm (18:00 to approximately 21:00), we welcome participants to Berlin and the Patagonia Conference with a casual open-air get-together. The venue is located at the inner yard behind "Haus 1" of Humboldt-Universität, Luisenstraße 56, 10117 Berlin, and the building of the famous "Tieranatomisches Theater". You can enter the area from both sides but most easily through the neo-classical building at Luisenstraße 56.

On Saturday, 15th July, 9:30 am, we meet at Checkpoint Charlie, located in downtown Berlin on the corner of Friedrichstraße and Zimmerstaße (station Kochstraße on metro-line U6 or station Stadtmitte on metro-line U6 or U2 are close by) from where we will go for a longer walk to see some of Berlin's monumental sights. At 1 pm (13:00), we will take a boat trip through Berlin's city centre on the river Spree up to the famous East-Side-Gallery, a remnant of the Berlin Wall. Afterwards (in the afternoon) we will walk through the vibrant district Kreuzberg to finally arrive at a popular rooftop location ('Klunkerkranich') to end the day.

On Sunday, 16th July, we will meet in front of the train station 'Berlin Zoologischer Garten' at 9:00. At 09:17 we take the train RE 4 towards ‚Magdeburg Hbf' from track 4. We'll get off at Potsdam Hbf (main station) at 09:36. You can as well board this train elsewhere in Berlin:

Berlin Ostbahnhof 08:59, track 6; Regional-Express towards ‚Magdeburg Hbf'

Berlin Alexanderplatz 09:03, track 2	Berlin Friedrichstraße 09:07, track 3
Berlin Hbf (main station) 09:11, track 14	Berlin Zoologischer Garten 09:17, track 4
Berlin-Charlottenburg 09:21, track 3	Berlin Wannsee 09:30, track 5
Potsdam Hbf (main station), 09:36, track 3	

(For those already in the train, or boarding it after 'Zoologischer Garten': we meet in the last coach.)

From Potsdam main station, we continue on Tram line 96 at 09:41. We'll get off the tram at station 'Puschkinallee' in Potsdam at 09:51.

We will have a pleasant walk up to the Belvedere on Pfingstberg (800 m distance) with hopefully pleasant weather and marvellous views over some of the glacier-shaped landscapes of the Berlin-Brandenburg area. After a nice walk back through a park area we head on to Potsdam City Centre by tram where you might grab a sandwich for lunch.

After midday we get back to Potsdam Main station by Tram. From there it is a walk of about 30 minutes up to the famous Telegrafenberg with its impressive large refractometer, an astronomical device from the late 19th century and the "Einstein Tower". We'll be getting a tour offered on Telegrafenberg that lasts about 1.5 hours. After returning to Potsdam Main Station by foot we take any regional train or S-Bahn to bring us back to Berlin Centre.

Additional Information on the by-programme Friday, July 14th – Sunday, July 16th, 2017

Please have your train and tram tickets purchased and stamped by yourselves before boarding public transport. For Sunday the most convenient will be a day ticket for zones ABC for 7.70 EUR of VBB. (VBB: public transport in the Berlin & Brandenburg area; AB covers most of Berlin, the additional zone C covers all of Potsdam as well.) You can get that combination ticket from any ticket machine in Berlin or Potsdam or from the BVG/VBB shops in the major stations.

(We will not visit the very touristic, world-famous Park and Castle Sanssouci in Potsdam but rather like to show you sights off the beaten track. However, you are always free going wherever you like by yourselves.)

We are very much looking forward to welcoming you to Berlin for this by-programme and of course the following conference and workshop. Please don't hesitate to contact the conference convenors in case of any questions or inquiries.

Conference Programme, Monday July, 17th – Tuesday, July 18th, 2017
Monday, July, 17th, 2017 - starting Berlin Mitte - Unter den Linden 6

08:30	Registration (Senate Hall)
09:00	Opening speeches
09:00	Welcome by the Scientific Convenor (Christoph Schneider)
09:05	Welcome address: Vice President for Academic Affairs, Humboldt-Universität zu Berlin (Eva Inés Obergfell)
09:15	Welcome address: Chargé d'Affaires, Embassy of Chile (Víctor Abujatum)
09:25	Welcome by the GABY-VASA project Principal Investigators (Gino Casassa)
09:30	Schneider, C. et al.: Climate Impacts on Glaciers and Biosphere in Fuego-Patagonia
09:40	Izagirre, E. at al.: Incognita Patagonia (documentary film presentation)
10:10	Short Coffee Break
10:30	*Session 1: Glacial Geology; Chairperson: Matthias Braun*
10:30	Davies, B. et al.: Dynamics and fluctuations of the Patagonian Icefields from the LGM to present: A review of glacier extent and chronologies
10:50	Bravo, C. et al.: Air temperature differences and melt estimated from a weather station network in the South Patagonian Icefield
11:10	*Session 2: Glacier Remote Sensing I; Chairperson: Matthias Braun*
11:10	Wilson, R. et al.: Evolution of glacial lakes in the central and Patagonian Andes between 1985 and 2016: Implications for GLOF risk assessment
11:30	Malz, P. et al.: Geodetic Mass Balance From TanDEM-X In The Southern Andes, Patagonia
11:50	Floricioiu, D. et al.: Geodetic mass balance of the Patagonia Icefields derived from SRTM and TanDEM-X data
12:10	Blindow et al.: Ice thickness and bed topography from airborne GPR measurements on Glaciers Tyndall and Grey
12:30	Lunch Break & Transfer to Berlin-Adlershof
14:30	*Session 3: Lake sediments; Chairperson: Jussi Grießinger*
14:30	Mayr, C. et al.: Oxygen isotopes from Patagonian lakes as palaeoclimate proxies
14:50	Roberts, S. et al.: Developing quantitative Southern Hemisphere temperature reconstructions from Antarctic & sub-Antarctic lakes
15:10	Jouve, G. et al.: Lake level reconstruction since the AIM4 inferred from micro-scale sedimentological, geochemical and biological analyses of Potrok Aike lake sediments
15:30	Kilian, R. et al.: Holocene glacier fluctuations in the sw Patagonian Andes and their forcing
15:50	Coffee Break
16:20	*Session 4: Biological Indicators & paleo climate; Charperson: Christoph Mayr*
16:20	Grießinger, J. et al.: Disentangling moisture origins in δ18O tree-ring time series from Lago Argentino
16:40	Meier, W. et al.: A history of the oscillations of Schiaparelli glacier since the Little Ice Age derived from tree-ring based moraine dating
17:00	Hebel, I. et al.: Moraine ecology and genetic diversity: A comparison of the moss colonization after glaciers retreat in Southern Patagonia
17:20	Soto-Rogel, P. & J.C. Aravena: Dendroclimatic analysis of Nothofagus betuloides forests from Cordillera Darwin, Tierra del Fuego, Chile (presenting author: Aravena, J.C.)
17:40	Rodríguez-Catón, M. & R. Villalba: Droughts as triggers of Nothofagus pumilio growth decline in northern Patagonia, Argentina (presenting author: Rodríguez-Catón, M.)

Tuesday, July, 18th, 2017 - full day at Campus Berlin-Adlershof, Rudower Chaussee 26

09:00	*Session 5: Glacier energy balance and atmospheric sciences; Chairperson: Gino Casassa*
09:00	Sauter, T.: Moisture transport mechanisms in Patagonia
09:20	Weidemann, S. et al.: Comparison of modeled surface energy and mass balance variations of Grey and Tyndall Glacier at the Southern Patagonia Icefield
09:40	Schaefer, M. et al.: The Energy Balance of Chilean Glaciers
10:00	*Poster Short Presentations*
10:40	*Poster Session I & Coffee Break*
12:00	*Session 6: Glacier mass balance I; Chairperson: Gino Casassa*
12:00	Jaña, R. et al.: Surface altitude change assessment by means of DGPS measurements at Grey and Schiaparelli glaciers
12:20	Minowa, M. et al.: Changes in calving glaciers and glacier-lake interaction in the Southern Patagonia Icefield
12:40	Fürst, J.J. et al.: Mapping glacier thickness in Patagonia using a mass conservation approach
13:00	*Lunch Breack*
14:00	*Session 7: Antarctic peninsula; Chairperson: Ricardo Jaña*
14:00	Marinsek, S. et al.: Significant mass loss recorded in Glaciar Bahía del Diablo, Vega Island, Antartic Peninsula
14:20	Szilo, J. et al.: Climate impact on Baranowski Glacier and its reaction to hydrological conditions (King George Island, W Antarctica)
14:40	Braun, M. et al.: Changes in glacier dynamics and mass budgets of the Antarctic Peninsula
15:00	*Session 2 contuinued: Glacier Remote Sensing II; Chairperson: Ricardo Jaña*
15:00	Le Bris, R. et al.: Glaciers of Patagonia in 2016: A new inventory from Landsat 8 and analysis of changes
15:20	*Poster Session II & Coffee Break*
16:20	*Session 8: Glacier mass balance II; Chairperson: Marius Schäfer*
16:20	Casassa, G. et al.: Evolution and fate of remnant ice detached from Marinelli Glacier, Cordillera Darwin
16:40	Espinoza, D. et al.: Recent behavior of the Amalia and Grey glaciers and its relation with a possible activity of the Reclus volcano and the local environmental conditions
17:00	Weidemann, S. et al.: Recent work on surface energy and mass balance modelling using meteorological and glaciological observations at Schiaparelli Glacier, Cordillera Darwin (presenting author: Schneider, C.)
17:20	Scheiter, M. et al.: Implementing a Parametrization for Snow Drift on Mocho Glacier (40°S, Chile)
17:40	Conference summary & outlook to Wednesday's meeting

Workshop Programme, Wednesday, July, 19th

Campus Berlin-Adlershof, Rudower Chaussee 26, Conference Hall

Preliminary tentative open schedule:

9:00: Welcome
9:00: Introductory remarks by the project PIs (Gino Casasaa, Ricardo Jaña, Juan Carlos Aravena, Ingrid Hebel & Christoph Schneider)

9:15: Achievements of the GABY-VASA Project
9:15: Overview Fieldwork: campaigns 2015, 2016, 2017 and planned ones in 2017 & 2018 (Ricardo Jaña)
9:40: Overview over results and remaining/continued work programme of dendro-ecological work in GABY-VASA (Juan Carlos Aravena & Wolfgang Meier)
9:40: Results and remaining/continued work programme of mosses (Ingrid Hebel)
9:50: Results and remaining/continued work programme of glacier remote sensing work (N.N., FAU Erlangen)
10:05: Results and remaining/continued work programme of glacier mass balance (Stephanie Weidemann/Christoph Schneider) and glacier bedrock topography (Gino Casassa)

10:20: Coffee Break

11:00: Further steps for the GAYB-VASA consortium (all PIs and scientists in the programme)
11:20: Next generation scientific questions (open panel discussion)
12:00: Funding opportunities for follow-up activities for an extended GABY-VASA project?
12:20: Prospects of joint European Union funding opportunities for integrated geo-system research in Patagonia, Tierra del Fuego and the Antarctic Peninsula
12:40: Open discussion on further strategies and options for joint international research on Climate, Hydrosphere, Glaciers & Biosphere/Ecology in Patagonia
13:00: Concluding remarks & closing of the workshop (Gino Casassa & Christoph Schneider)
13:15. End of GABY-VASA workshop

Poster Presentations		
	Glacial Geology	
1	Jacob Bendle et al. (presenting author: Varyl Thorndycraft):	Reconstructing the dynamics of ice marginal processes during Late Quaternary deglaciation of the Northern Patagonia Icefield
2	Claire Donelly et al.:	Estimating the ice thickness of the Patagonian Icefields through mass conservation
3	Guisella Gacitúa	First results of ice thickness measurements of Schiaparelli glacier
4	Eñaut Izagirre et al.:	Glacier change and concurrent GLOF events in southernmost South America, Tierra del Fuego, Chile
5	Erling Johnson et al.:	An algorithm for calving flux retrieval, applied to mayor outlet glaciers from South Patagonia Icefield
6	Ryan Wilson et al.:	Glacial Hazards in Chile: Processes, assessment, mitigation and risk management strategies
	Glacier Remote Sensing	
7	Francisco Aguirre et al.:	Snow variability in Southwestern Patagonia from MODIS satellite data
8	Jorge Arigony-Neto et al.:	First results of UAV surveys at Schiaparelli and Grey glaciers
9	Rubén Carvallo et al.:	Real-time transmission of time-lapse imagery in Fuego-Patagonia and central Chile
10	Inti Gonzáles et al.:	Gaby-VASA multidisciplinary geographic platform for data integration
11	Andrés Lo Vecchio et al.: (presenting author: Milagros Rodríguez-Catón)	Estimation of speed and surface temperature from optical satellite imagery at Viedma glacier, Argentina
12	Wolfgang Meier et al.:	A new multi-temporal glacier inventory for Southern America (49°S-55°S)
13	Julia Neelmeijer et al.:	Sentinel-1-based measurements of loading effects: an example from the Toktogul Water Reservoir, Central Asia
	Paleo-climate	
14	María Lujan García et al.:	Palaeoenvironmental changes in southern Patagonia inferred from the Lake Gemelas Este record
15	Melina Mauad et al.:	The project OXICLIM – synthesis of oxygen isotope proxies for climate reconstruction in southern Patagonia
16	Neil L. Loader et al.:	Stable isotopic analysis of a late-Holocene peat sequence from Patagonia
17	Ana M. Srur et al. (presenting author: Milagros Rodríguez-Catón):	Establishment of Nothofagus pumilio at upper treelines across precipitation gradients. Part II: The Southern Patagonian Andes
	Atmospheric Sciences	
18	Villalba, R. et al.: (presenting author: Rodríguez-Catón, M.)	Contrasting precipitation and temperature patterns in the Southern Andes related to the recent shift in the Antarctic Oscillation Index
19	Katherine Raquel Gaete Beltrán et al.:	Regional Climate Models performance by precipitation and temperature analysis in Fuego – Patagonia
20	Lukas Langhamer et al.:	Lagrangian Moisture Source Detection of the Southern Patagonia Icefield
21	Matthias Scheiter et al.:	Implementing a Parametrization for Snow Drift on Mocho Glacier (40°S, Chile)
22	Guilherme Tomaschewski Netto et al. (presenting author: Jorge Arigony-Neto):	Low-cost autonomous stations for measuring glacier ablation and meteorological parameters on Patagonian glaciers
	Glacier energy and Mass balance	
23	Claudio Bravo et al:	Air temperature differences and melt estimated from a weather station network in the South Patagonian Icefield
24	Gabriela Collao Barrios et al.:	Ice-flux and regional climate modeling to constrain the surface mass balance and ice discharge of San Rafael Glacier, northern Patagonia
25	Ines Dussaillant et al.:	Geodetic Mass Balance of the North Patagonian Icefield (46 - 47°S) during 2000-2012. Comparison of two independent estimates based on satellite data.
	Antarctic Peninsula	
26	Marta M. Caballero et al.:	Effects of clouds on the energy balance of the Antarctic Peninsula Ice Sheet
27	Fernandoy Francisco et al. (presenting author Guisela Gacitúa):	40 year firn core record from the Schanz-Schneider glaciers divide, Ellsworth Mountains, Antarctica
28	Kirstin Hoffmann et al.:	High-resolution isotope-geochemical records of firn cores from the northern Antarctic Peninsula as tools for studying climate variability
29	Schwalbe, E., R. Koschitzki et al.:	Determination of spatio-temporal velocity fields at Grey Glacier using terrestrial and satellite imagery [late poster contribution]

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Atmospheric Sciences – Poster Presentations (continued)

Glacier Mass Balance – Oral Presentations

Glacier Energy and Mass Balance – Poster Presentations

Antarctic Peninsula – Oral Presentations

Antarctic Peninsula– Poster Presentations

Glacial Geology **Oral Presentations**

Dynamics and fluctuations of the Patagonian Icefields from the LGM to present: a review of glacier extent and chronologies

B. Davies[1], A. Hein[2], N. Glasser[3], S. Blockley[1], I. Wolff[3], C. Darvill[4], H. Lovell[4], M. Pelto[5], R. Smedley[3], J. Smellie[6]

1-Royal Holloway University of London
2-Edinburgh University
3-Aberystwyth University
4-Portsmouth University
5-Nichols College
6-Leicester University

Abstract

The Patagonian Icefields are among the highest latitude and most sensitive icefields in the Southern Hemisphere, and are responding sensitively to climate. Their response to rapid climate changes during the Last Termination and during Holocene palaeoclimatic fluctuations has the potential to elucidate changes in large scale atmospheric circulation as well as aid better predictions of their future response to climate change. The application of numerous forms of dating techniques to glacigenic deposits in Patagonia, including cosmogenic nuclide dating, optically stimulated luminescence dating, radiocarbon dating, potassium/argon dating, combined with updated detailed geomorphological mapping, means that we now have a comprehensive dataset that constrains icefield fluctuations over the last 30,000 years.

However, variations in calibration curves, corrections, and calculation methods mean that comparing different published datasets is challenging. According to published data, the timing of the last glacial maximum, and rates of recession, varies latitudinally across the icefields. However, this hypothesis is challenging to test without compiling all published ages and applying a uniform method of calculating and recalibrating ages.

The aim of this review is therefore to present a state-of-the art compilation of published glacial geomorphology and chronostratigraphy in order to generate a new, updated reconstruction of the Patagonian Ice Sheet at the Last Glacial Maximum. We apply Bayesian Modelling to best determine the age of the mapped moraines. Isochrones of ice extent at 5 ka time slices will then be generated across the ice sheet. Using these isochrones, we will be able to generate palaeo ice-sheet reconstructions from 30 ka until the present day.

Glacial Geology **Oral Presentations**

Glacial isostatic adjustment of the Southern Patagonian Ice-Fields as a natural experiment for sounding the underlying lithosphere structure

V. Klemann[1], M. Motagh[1], M. Bagge[1]

1-German Research Centre for Geosciences GFZ, Potsdam Germany

Abstract

withdrawn

Glacial Geology **Poster Presentations**

Poster #1

Reconstructing the dynamics of ice marginal processes during Late Quaternary deglaciation of the Northern Patagonia Icefield

J. Bendle[1], G. Benito[2], A. Palmer[1], V. Thorndycraft[1]

1-Department of Geography, Royal Holloway University of London UK
2-Museo Nacional de Ciencias Naturales, CSIC, Spain

Abstract

This poster presents an overview of recent studies by our research group in the region of the Northern Patagonia Icefield (46-48 ºS). Over the last 5 years we have carried out: 1) high resolution geomorphological mapping using remote sensing (mainly 2.5 m resolution SPOT-5 and 1-m resolution DigitalGlobe (GeoEye-1, IKONOS) images available through the ESRI™ 'World Imagery' service); 2) detailed field mapping and sedimentology on a range of glacial, glaciofluvial, lacustrine and fluvial landforms; 3) detailed field and micromorphological analyses of glaciolacustrine varves; and 4) palaeoflood hydrological studies to investigate the magnitude and timing of glacial lake outburst floods (GLOFs). The main outputs of this research include: 1) a new geomorphological map of the region covering 70-74 ºW and 46-48 ºS; 2) an annually-resolved chronology for Lago General Carrera/Buenos Aires; 3) the mapping of megaflood (*ca*. 10^5 m^3/s) pathways; 4) magnitude/frequency records of GLOF events (*ca*. 10^4 m^3/s) linked to Holocene neoglacials; and 5) re-evaluation of published models of palaeolake evolution during NPI deglaciation. Here, we present our new geomorphological map as the focal point of the poster, and highlight some of the key advances in our understanding of ice marginal processes during Late Pleistocene and Holocene retreat of the NPI.

Glacial Geology **Poster Presentations**

Poster #2

Estimating the ice thickness of the Patagonian Icefields through mass conservation

C. Donnelly[1], T. Payne[1], S. Cornford[2], M. Schaefer[3], A. Orr[4]

1-University of Bristol, UK
2-Swansea University, UK
3-Universidad Austral de Chile, Chile
4-British Antarctic Survey, UK

Abstract

The majority of the outlet glaciers of the Patagonian Icefields have been rapidly losing mass in recent decades. However, due to the difficulty of surveying them, their total volume is currently not known. Radar sounding is challenging due to high absorption and scattering resulting from the presence of englacial water, crevasses and steep terrain in Patagonia, which has limited thickness measurements to about 700 m. However, recent measurements from helicopter-borne gravimetry suggest that the ice thickness may be larger than 700 m in some areas, although the coverage of these observations is 49% and 30% of the North and South Patagonian Icefields respectively. Therefore, there is currently no complete observational dataset of bedrock topography or ice thickness for the Patagonian Ice fields.

In this study, we use a mass conservation approach, coupled with an optimisation process to estimate ice thickness for part of the Northern Patagonian Icefield. Our results show that we are able to estimate thickness without requiring an observational thickness dataset. This method could potentially be used to model the remainder of the icefields, as well as other glaciers worldwide, where thickness measurements are sparse and difficult to obtain.

Glacial Geology **Poster Presentations**

Poster #3

First results of ice thickness measurements of Schiaparelli glacier.

G. Gacitúa[1]

1-Universidad de Magallanes (UMAG)

Abstract

Within the framework of the GABY-VASA project, and in conjunction with the field campaign team (April 2016), successful ice thickness measurements were performed in the ablation area of Schiaparelli glacier. This is the first record of the Schiaparelli ice pack thickness. Data were collected along a ~3.1 km track using a ground-penetrating radar (GPR) of resistive dipole antennas (8 m each) operating at approximately 10 MHz central frequency. Data collection was restricted by the characteristic difficulties of a glacial traverse; yet a nearly full transversal line was performed. GPR data revealed a fairly clear bedrock reflector and after minor processing and geometrical correction, the data show a maximum ice thickness of 324 m in the central part of the valley.

Poster #4

Glacier change and concurrent GLOF events in southernmost South America, Tierra del Fuego, Chile

E. Izagirre[1], E. Miles[2,3], I. Rico[4,5]

1-Dirección de Programas Antárticos y Subantárticos, Universidad de Magallanes, Punta Arenas, Chile.
2-Scott Polar Research Institute, University of Cambridge, Cambridge, United Kingdom
3-School of Geography, University of Leeds, Leeds, United Kingdom
4-Pyrenean Institute of Ecology, CSIC, Jaca, Spain
5-Department of Geography, Prehistory and Archaeology, University of the Basque Country, Vitoria-Gasteiz, Spain

Abstract

Due to extreme remoteness and poor weather, in-situ observations are scarce for the glaciers and icefields in southern South America, with most studies relying exclusively on aerial and satellite imagery. To improve the balance of data sources, we visited the Cloue Icefield (55º10' S, 69º43' W) on Hoste Island (Chilean Tierra del Fuego) in March-April 2016, surveying glacier terminus positions, select terrestrial LIA moraines and recent recessional moraine systems. One glacier showed a well-preserved set of landforms indicating a glacier lake outburst flood (GLOF) lowering water levels ~35m. We conducted extensive surveys of the landforms and analysed tree cores to date the event to 1997-8.

We contextualise this event with a multidecadal analysis of glacier change for 1945-2016, using Trimetrogon (1945) and CORONA (1966) aerial images as well as the Landsat archive (1979-2016). The icefield area was 255.9 km^2 in 1945 and decreased in area by 16.3 % by 2016 to cover 214.2 km^2. The icefield's land-terminating glaciers showed gradual shrinkage for the early period, and more enhanced retreat after 1979, when large proglacial lakes started expanding as glaciers retreated. In addition to the observed GLOF site, several proglacial lakes have expanded rapidly in the past few decades, but pose little hazard as the zone is uninhabited.

Finally, the late-1990s Landsat imagery reveals that this outburst and a second, much larger GLOF event partially draining ice-dammed Lago Mateo Martinic (9.85 km^2) in the Cordillera Darwin both occurred between March 1997 and February 1998, a remarkable coincidence. We consider the possibility of local outburst mechanisms at each site, and note that several moderate (M~5.0) earthquakes occurred in the region during this period that could have triggered both drainage events simultaneously.

Poster #5

An algorithm for calving flux retrieval, applied to mayor outlet glaciers from South Patagonia Icefield

E. Johnson[1,2], D. Floricioiu[2], W. A. Jaber[2]
1- University of Magallanes (UMAG), Punta Arenas, Chile
2- German Aerospace Center (DLR/IMF), Oberpfaffenhofen, Germany

Abstract

Calving glaciers are important contributors to the global sea level rise. In order to better understand the variations in ice flow dynamics and their response to climate change, the estimation of the total glacier mass balance and of its individual components are necessary. This can be done by applying the input/output method which differentiates the total input with the total output of ice. In the case of calving glaciers near the accumulation and ablation the ice export due to the discharge to the open water or an ice shelf is an important component of the change in ice mass.

The South Patagonia Icefield (SPI) belongs to a region of high climate sensitivity and has a significant number of calving glaciers. The present study estimates the ice export at the calving front (calving flux) for main outlet glaciers of SPI. We are using an empirical relationship between the frontal glacier width, mean glacier thickness and the calving rate. The front position of the glacier terminus is automatically detected or manually delineated and is further needed for the frontal width determination and for the displacement of the calving front. The surface ice velocity is calculated by means of offset amplitude tracking applied to TerraSAR-X repeat pass acquisitions. Finally, the ice thickness at the glacier front can be obtained using the glacier surface elevation retrieved from a DEM (e.g. TanDEM-X bistatic data) combined either by ground penetrating radar (GPR) from the glacier-bed or bathymetry from the pro-glacial lake or fjord.

Glacial Geology **Poster Presentations**

Poster #6

Glacial Hazards in Chile: Processes, assessment, mitigation and risk management strategies

R. Wilson[1], N. Glasser[1], G. Casassa[2,3], J. Reynolds[4], S. Harrison[5], S. Shannon[5], M. Schaefer[6], P. Iribarran Anacona[6]

1-Department of Geography and Earth Sciences, Aberystwyth University, Ceredigion, UK.
2-Geoestudios, Las Vertientes, San José de Maipo, Chile.
3-Universidad de Magallanes, Punta Arenas, Chile.
4-Reynolds International Ltd, Broncoed House, Broncoed Business Park, Mold, UK.
5-College of Life and Environmental Sciences, University of Exeter, Penryn, Cornwall, UK.
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Abstract

Having the ability to travel considerable distances from their source, Glacial Lake Outburst Floods (GLOFs) represent one of the most important glacial hazards. In line with observations in other parts of the world, the frequency of GLOF events in Chile has increased in recent decades highlighting the need to quantify the flood risk posed to downstream areas. This poster presents the work of the 'Glacial Hazards in Chile' project which aims to (1) better understand the processes that govern the development of GLOFs in Chile, (2) estimate the socio-economic effects of GLOFs in Chile, and (3) provide a GLOF risk assessment framework that can be applied to Chile and other lower income countries globally. As an initial step towards the completion of these aims, we have recently compiled the first glacial lake inventory for the central and Patagonian Andes, which details the temporal development of glacial lakes in this region over the past three decades. This analysis was used to identify two lakes of interest that were visited during a fieldwork expedition in February 2017. The first of these, Lago Chileno in Patagonia, has recently produced a large GLOF causing significant damage to the downstream floodplain, whilst the second was identified as one of the fastest growing lakes in the central Andes. Both these lakes were surveyed using drone acquired aerial imagery and a custom-built bathymetry boat, data from which will help to improve our understanding of the physical processes associated with glacial lake development and failure within the Chilean Andes.

Evolution of glacial lakes in the central and Patagonian Andes between 1985 and 2016: Implications for GLOF risk assessment

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Abstract

Glacial lakes are important both on a global and regional perspective as they (1) effectively delay and/or reduce ice melt contributions to global sea level rise, (2) can have negative impacts on glacier mass balance and (3) are the source of potentially catastrophic Glacial Lake Outburst Floods (GLOFs). Having the ability to travel considerable distances downstream from their source, the socio-economic impact of GLOFs, in particular, can be severe. The prevalence and increased frequency of high-magnitude GLOFs in the Chilean and Argentinean Andes suggests this region will be prone to similar events in the future as glaciers continue to retreat and thin under climate change. Despite this situation, monitoring of glacial lake development in Chile and Argentina has been limited, with past investigations covering relatively small regions of Patagonia. In this study we present the results of a new glacial lake inventory covering all of the central and Patagonian Andes. Our aim was to characterise the physical attributes, spatial distribution and temporal evolution of glacial lakes in the central and Patagonian Andes using Landsat satellite imagery (acquired for 1986, 2000 and 2016) and other high-resolution image datasets available in Google Earth. Additionally, glacial lake water volume was also estimated using an empirical area-volume scaling approach. This analysis represents the first large-scale census of glacial lakes in Chile and Argentina and will allow for a better understanding of the processes that govern lake development in this region, as well as, providing a basis for future GLOF risk assessments.

Geodetic Mass Balance from TanDEM-X in the Southern Andes, Patagonia

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Abstract

The Patagonian Ice Fields are, with a total size of about 17 000 km², two of the largest connected ice-bodies beyond the polar circles. The mass loss they have shown so far is remarkably high in comparison to their size. This implies a better knowledge and quantification of the ongoing changes. The elevation changes to derive geodetic mass balances are calculated from repeat TanDEM-X data between 2012 and 2016, processed to DEMs by SAR-interferometric methods. Since the TanDEM-X data covers different seasons, it allows for analysis of multi-year changes but also for seasonal differences and influence of radar penetration.

The results show a large variation in geodetic mass balances. We observe an altitude dependence of the elevation changes, whereas a clear east-west pattern could not be distinguished. The elevation change rates reach a maximum of -10 m per year. The mass loss amounts to 14 Gt (2000-2014) for the SPI area south of 50.3° S.

Geodetic mass balance of the Patagonia Icefields derived from SRTM and TanDEM-X data

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Abstract

The behavior of the Patagonia Icefields, the largest temperate ice body in the Southern Hemisphere, has been subject of several studies related to their mass balance in the recent years. Recent global low resolution mass estimates for glaciers and ice caps as well as DEMs derived from optical data show significant mass deficits for many ice-covered regions over the world including the Northern and Southern Patagonia Icefields (NPI and SPI).

In the present study, high resolution Raw DEMs produced by the TanDEM-X mission were combined with the SRTM C-band DEM of year 2000 over NPI and SPI. These represent a powerful and reliable multitemporal dataset based on bistatic SAR interferometry (InSAR) to compute the geodetic mass balance of these vast regions featuring one of the largest sea level rise contribution per unit area worldwide. From the elevation change maps integrated over the glacier area the volume change rate is computed which in turn can be converted into mass trend via the density of the depleted or gained volume. In our work a particular emphasis was set on the definition of a generalizable framework for the estimation of the uncertainty of the geodetic mass balance by quantifying all relevant sources of error. Among these, signal penetration into dry ice and snow, which can affect considerably radar elevation measurements, was assessed through the backscattering coefficient.

Glacier Remote Sensing **Oral Presentations**

Ice thickness and bed topography from airborne GPR measurements on Glaciers Tyndall and Grey

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Abstract

During austral fall in 2008, an exhaustive survey using an airborne radar system was performed on the Southern Patagonian Icefield (SPI). The ice radar system was designed and developed at University of Münster. UMAIR (University of Münster Airborne Ice Radar) was first tested on the temperate ice of Glaciers Tyndall and Grey. Glaciers Tyndall and Grey are two of the largest southernmost glaciers of the SPI draining into lakes, both have experienced thinning and retreating during the last decades. In some areas ice thickness unexpectedly exceeded 800 m and the initial system setting prevented deeper detection.
On the whole, the dataset has both good quality and coverage of the glaciers surface, thus data processing and a proper depth conversion using a 2D velocity model lead to the first mapping of these glaciers bedrock topography. We also compare with more recent measurements using ground penetrating radar at few locations. Further analyses of these radar data allow us to get insight into their ice structure and its developing dynamics.

Glacier Remote Sensing **Oral Presentations**

Recent elevation changes in Northern Patagonia Icefield by SAR remote sensing and ground based

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withdrawn

Glaciers of Patagonia in 2016: A new inventory from Landsat 8 and analysis of changes

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Abstract

A recent study revealed that glaciers in Northern Patagonia, including the larger ones, have shown a dramatic shrinkage over the past three decades. Consequently, the landscape is changing rapidly, glacier fore-fields grow and new and / or growing lakes can often be found where glacier ice had been a decade ago. These rapid changes require repeating glacier inventories more frequently than elsewhere. Unfortunately, adverse weather conditions with clouds and seasonal snow remaining at high elevations allow only regional inventory updates. In March 2016, however, more or less cloud free Landsat 8 scenes were acquired under near-optimal snow conditions covering the entire region from Mt. Tronador to the Gran Campo Nevado ice cap.

This study presents the results of a new inventory for 2016 (encompassing about 21 300 km2 of ice) along with glacier area changes since 1985 / 2000 for several regions in Patagonia. The study also extends on currently used methods for glacier classification. In particular, the outlines for 2016 are derived from the 15 m resolution panchromatic band of Landsat 8, two different thresholds are applied with the band ratio method to better map ice in shadow, the new TanDEM-X DEM is used to derive drainage divides and topographic parameters, lakes and other water are classified automatically, and the year 2000 outlines in the RGI are improved. We also use Sentinel-2 images acquired in February 2017 for validation and correction of seasonal snow in the northern part of the study region. Y radar elevation measurements, were assessed through the backscattering coefficient.

Poster #7

Snow variability in Southwestern Patagonia from MODIS satellite data

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Abstract

In order to infer future snow scenarios, it is relevant to know the past snow cover variability and its relationship with significant climate variables. At present, no systematic study on snow cover variability and its relationship with climate trends has been performed in Fuego-Patagonia. In this work, we assess snow cover variability for the Brunswick Peninsula in Patagonia (53°- 54°S, 70°50'-71°50'W) based on MODIS satellite data. We use here the 8-day maximum binary snow cover product from the Moderate Resolution Imaging Spectroradiometer Sensor (MODIS) within the period 2000-2016. A spatial-temporal index for snow and cloud cover from MODIS´s data analysis developed by Richer et al. (2013) is used. To address the effect of elevation, we use a digital elevation model (DEM) using tiles of the year 2000 Shuttle Radar Topography Mission (SRTM) version 3.0, at 30-meter spatial resolution. Our objectives are to: (1) reconstruct the historical snow cover variability for the study area; and (2) validate and adjust the satellite-derived model with field data for the study area.

Poster #8

First results of UAV surveys at Schiaparelli and Grey glaciers

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Abstract

During the last years, unmanned aerial vehicles (UAVs) grew in importance as one of the most reliable tools for acquiring high-resolution imagery for environmental applications. As part of GABY-VASA complementary efforts for setting benchmark observational sites at Schiaparelli and Grey glaciers, we carried out a series of UAV surveys on selected areas of these glacial systems during the field campaigns of October 2016 and March 2017. During the presentation, we will give an overview on the orthophotos and digital elevation models (DEMs) generated by processing the digital pictures acquired by the UAV used in both campaigns. We also plan to show some examples on the use of these products for estimating spatial patterns of mass balance at Schiaparelli glacier, mapping glacial landforms and identifying different stages of vegetation colonisation on areas recently free of ice. Additionally, we would like to discuss the further potential of using UAVs for measuring meteorological parameters at both Schiaparelli and Grey sites, as well as special needs of other groups working in the area.

Poster #9

Real-time transmission of time-lapse imagery in Fuego-Patagonia and central Chile

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Abstract

Time lapse cameras provide valuable imagery for the study of glaciers, such as Glacial Lake Outburst Floods (GLOFs), ice calving of tidewater and freshwater fronts, ice velocity, glacier albedo and geometric changes. As part of the GABY-VASA CONICYT BMBF project "Responses of Glaciers, Biosphere and Hydrology to Climate Variability across the Southern Andes" and the FONDEF project "Development of terrestrial and airborne sensors onboard UAVs for the monitoring of albedo on glaciers", time-lapse cameras have been installed at glacier fronts in Fuego-Patagonia and central Chile. Time lapse imagery is generally of high resolution and constitutes large data sets which are normally used in post-processing mode, retrieving the imagery in the field every few months or even at a yearly time interval. Real time availability of the imagery is of high interest in special cases such as early warning systems, monitoring of large changes which require urgent field measurements, and also for detection of lapse rate camera failure. We present here different designs of data transmission systems which allow to transmit in real time all or part of the imagery. WiFi, WiMax, RF (HF or VHF) and satellite transmission systems are proposed. In order to decrease costs, in the case of satellite transmission a smaller subset of the original image can be transmitted installing a microprocessor unit in the field. Technical characteristics and cost issues are discussed and compared for each of the different systems.

Poster #10

Gaby-VASA multidisciplinary geographic platform for data integration

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Abstract

A data platform based on a Geographical Information System (GIS) is a relevant tool to manage raster and vector datasets, allowing to store, visualize, integrate, analyze and represent multidisciplinary collections. Free and open source software is an added advantage of such a data platform, facilitating cooperative management of datasets. An example of this approach has been performed by the Norwegian Polar Institute through the creation of Quantarctica (Matsuoka et al., 2013), a free application for non-commercial use, such as research, education, and operation in Antarctica, based on the QGIS free software.

Starting in 2013 the glacier terminus at Grey Glacier (50°58'S, 73°13'W) and Schiaparelli Glacier (54°23'S, 70°52'W), have been surveyed for glaciological and climatological monitoring. Since 2015 the GABY-VASA project has broadened the science scope to include the sampling of vegetation such as mosses and tree leaves for genetic analysis and tree-ring samples for dendrochronological reconstructions. All these data are being integrated to the GIS platform which is hereby described.

Poster #11

Estimation of speed and surface temperature from optical satellite imagery at Viedma glacier, Argentina

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Abstract

The spatial, spectral and temporal performance of remote sensing data enables the accurate modeling of glacier physics and dynamics. The combination of different spectral bands at diverse wavelengths of the electromagnetic spectrum allows for simultaneously obtaining complementary data of diverse glacier characteristics. The Southern Patagonian Icefield is one of the largest freshwater reservoirs of the World and the glaciers therein have shown dissimilar behaviors. In order to better understand glacier dynamics, surface velocities and temperatures are considered to be good indicators. In this study, we calculate surface velocities and temperatures of Viedma glacier and analyze the correlation between both variables using Landsat 8 data for the years 2014, 2015 and 2016. The Feature Tracking technique was utilized to retrieve glacier velocities, whereas temperatures were obtained by means of the single-channel method (NCEP). Velocities at the glacier terminus reached a maximum of 3 ±0.3md^{-1}, while the thermal data revealed minimum values of -2 ±0.29°C in the uppermost section of the glacier and maxima of 2 ±0.29°C at the glacier snout. This work is the first that applied multispectral analyses in bared glaciers at the SPI and which provided knowledge from to the relationship between deformation velocities and ice surface temperature.

Poster #12

A new multi-temporal glacier inventory for Southern America (49°S-55°S)

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Abstract

Since the end of the Little Ice Age, the area of the Northern and Southern Patagonian Ice sheet decreased by more than 14% and 11%, respectively. The melting increased since the last decade by 2.3%. The glaciers of Cordillera Darwin recorded a surface decrease of approximately 14% for the last 140 years. However reliable data is still missing, which obscures a complete picture of the cryosphere in South America. In order to facilitate comprehensive analyses of the southern hemispheric and global cryosphere a detailed new glacier inventory for the complete area between 49°S and 55°S including the Southern Patagonian Ice sheet, Gran Campo Nevado and Cordillera Darwin was established using Landsat Thematic Mapper (TM), Enhanced Thematic Mapper (ETM+), Operational Land Imager (OLI), Sentinel-2 and Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) satellite images from 1985–2016. Different mapping methods were applied to derive the glacial area for 1985/86, 1996/1997, 2005/06 and 2016/17, including Normalized Difference Snow Index (NDSI) and band ratio method. Using a semi-automatic approach, the central glacier flowlines were derived for all glaciers, which were employed to obtain multi-temporal length variations. Average snowline altitudes (SLAs) as an approximation for the equilibrium line altitude (ELA), as well as the accumulation-area ratio (AAR) were derived for all glaciers with respect to sufficient data quality. The newly acquired dataset of more than 4.500 glaciers is analyzed employing geostatistical methods with respect to occurring gradients, like the increase of the glacier mean elevation from the western to the eastern part of Cordillera Darwin of about 300 m. Small high altitude or steep glaciers are subject to a minor decrease in length and area. In contrast, big valley glaciers descending to sea level exhibit higher variability: Some glaciers show a surface area loss of up to 25% while others gained up to 5% area, corresponding to a maximum retreat of 10 km and a maximum advance of 2 km in the last 30 years. Once a proglacial lake is newly formed, the surface decrease at the glacial terminus is almost twice as high at comparable glaciers without adjacent lake.

Poster #13

Sentinel-1-based measurements of loading effects: An example from the Toktogul Water Reservoir, Central Asia

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Abstract

We apply the interferometric SAR (InSAR) Small BAseline (SBAS) algorithm on Sentinel-1 SAR data, acquired between November 2014 and December 2016, to investigate ground motion effects on the surroundings of the Toktogul water reservoir due to the water level variability.

The Toktogul dam in Kyrgyzstan was built in 1976 to store water of the Naryn River in the Toktogul water reservoir to facilitate hydroelectric power generation and for irrigation purposes. The reservoir has a total capacity of 19.5 cubic kilometers and seasonal fluctuations are in the order of 5 cubic kilometers and more, which corresponds to an approximate water level change of 20 meters. After the water level decreased to a minimum of 6.3 cubic kilometers in April 2015, less water had been released, leading to a maximum of 17.4 cubic kilometers in October 2016.

Our InSAR-based analysis suggests that the observed deformation is in the order of decimeters in flat areas close to the lake shore. The amplitude of the deformation signal is closely correlated to the seasonal changes of the lake water level. In future, we are going to extend our research also to the Patagonian region, were we will use the same method applied on Sentinel-1 data to quantify unloading effects related to the melting of the Patagonian ice sheet.

Oxygen isotopes from Patagonian lakes as paleoclimate proxies

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Abstract

The belt of the Southern Hemisphere Westerlies (SHW) is considered to have played an important role for global climate change. However, testing such a hypothesis is hampered by inconsistencies between both models and proxy records regarding intensity and latitudinal shifts of the SHW belt in the late Quaternary. Oxygen isotope proxies from lake sediments can be used to tackle questions related to past atmospheric dynamics and associated hydrological changes in Patagonia, presently located in the SHW core region. The modern database needed for the calibration of isotope proxies from this remote region, however, is extremely poor. To overcome this lack of data, samples of surface water and precipitation from Chilean and Argentinean Patagonia were investigated. The isotope ratios of precipitation strongly reflect spatiotemporal patterns caused by orographic, latitudinal, and continental effects. The water balance has a strong influence on the isotopic composition of lake water. Bathymetry, exposition to wind, inflows, outflows, and climatic settings influence the water balances of Patagonian lakes. As a consequence, the choice of adequate sites and of reliable recorders of the oxygen isotopic composition of the lake water is important. Methodologically refined isotope proxies, such as oxygen isotope ratios of aquatic cellulose, provided promising results in calibration studies. Combined oxygen isotope records from aquatic mosses and authigenic carbonates, continuously covering the last 26,000 years at the ICDP site Laguna Potrok Aike in the Patagonian steppe, indicated an early gradual warming starting around 18,000 years ago and extreme drought conditions in the early to mid-Holocene in the Patagonian steppe region. Future investigations aim at densifying the isotopic network and comparing isotope records from multiple proxies and archives.

Lake Sediments **Oral Presentations**

Developing quantitative Southern Hemisphere temperature reconstructions from Antarctic & sub-Antarctic lakes

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Abstract

We present a new high-latitude Southern Hemisphere temperature calibration dataset and quantitative reconstructions of past temperature change from Antarctic and sub-Antarctic lake sediments using glycerol dialkyl glycerol tetraethers (GDGTs - temperature-sensitive membrane lipids of Archaea and bacteria). The relative abundance of GDGTs in surface sediments has been used to create modern-day global temperature calibration models and reconstruct past temperature change in marine and terrestrial sediment records. However, the performance of global GDGT–temperature calibrations at lower temperatures and in high latitude terrestrial lacustrine environments is generally poor because GDGT presence, type and provenance remains unknown or uncertain. To address these issues, we quantified which GDGT compounds were present in surface sediments from 38 Antarctic, sub-Antarctic and Southern Chilean lakes and investigated modern-day environmental controls on GDGT composition. GDGT compounds were found in 37 of 38 lakes studied and branched GDGTs (brGDGTs) were dominant in 36 lakes. Multivariate statistical analyses showed that GDGT composition was more strongly correlated with mean summer air temperature (MSAT) than pH, conductivity or water depth. Since the GDGT-IIIb compound was absent in non-Polar lakes included in previous global calibrations, but present in 36 of the Antarctic and sub-Antarctic lakes examined in this study, we developed the first brGDGT–temperature calibration for Antarctic and sub-Antarctic lakes, based on four brGDGT compounds (GDGT-Ib, GDGT-II, GDGT-III and GDGT-IIIb). The inclusion of GDGTIIIb resulted in improved statistical performance at low temperatures. We then applied this new Antarctic brGDGT–temperature calibration model to two strategically-located lake sediment records from the Antarctic Peninsula (Yanou Lake) & South Georgia (Fan Lake). Downcore temperature reconstructions reproduced known phases of mid-late Holocene warmth, cooling and minor temperature variability better than global calibrations, and highlighted regional temperature leads and lags between the timing of temperature change on either side of the Polar Front in the South American/South Atlantic sector of the Southern Hemisphere.

Lake level reconstruction since the AIM4 inferred from micro-scale sedimentological, geochemical and biological analyses of Potrok Aike lake sediments

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Abstract

In Patagonia, lakes between 51 and 55°S are located at the interface between the modern and Last Glacial southern limit of the Southern Hemisphere Westerly Winds (SWW). At these latitudes, the strength and position of the SWW controls precipitation regimes that originate in the Atlantic Ocean. The paleohydrological and paleowind records obtained from lake sediments reveal latitudinal shifts of the SWW over time. Here we present results from the ICDP-PASADO project, and show how combining micro-scale sedimentology (especially tephra-derived particles), geochemistry (µ-XRF) and diatom analysis allows detailed reconstructions of past lake level changes and shifts in SWW intensity/position between 33 and 10 ka BP in Southern Patagonia (52°S).

The Antarctic Isotope Maximum 4 is an analogue of the current global warming and it strongly impacted SWW dynamics in South America as evidenced by decreases in the thickness of flood-induced turbidites, increases in wind burst deposits and the remobilization of emerged tephras, all of which reveal drier conditions and lower lake levels during this period. These results agree with paleoproductivity (diatom concentration) and paleowind (magnetic properties) from the same core. In addition, the cyclic diatom assemblage shifts, as well as the changes in Ca/Si (µ-XRF) and micropumice fragment profiles before, during and after the Antarctic Cold Reversal (ACR) and the Younger Dryas (YD) chronozones reveal at least five major lake level fluctuations. The periodicity of those lake level changes indicates millennial-scale variability of latitudinal SWW positions that correspond to Antarctic ice sheet discharge events during the Late Glacial.

Holocene glacier fluctuations in the southwestern Patagonian Andes and its forcing

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Abstract

The timing of Holocene glacier advances of the Southern Patagonian Icefield (PIF) have been in particular constrained by ^{14}C ages as well as cosmogenic nuclides. In general, they represent minimum ages while continuous records on past glacier fluctuations are missing. Partly inconsistent ages for the timing of these advances make it difficult to evaluate their temperature- versus accumulation-related forcing's or other influences on the glacier mass balances. We present first well-dated continuous Holocene glacial clay sediment records from the hyperhumid Andean fjord zone as well as subaquatic moraine mapping and its dating for an area to the west and south of the PIF (50 to 53°S). Two limited early Holocene advances (at ~10 kyr and from 8.5 to 7.9 kyr BP) and four Neoglacial advances from 5.4 to 4.9 kyr BP, 4.1 to 3.7 kyr BP, 2.34 to 2.1 Kyr BP (the most extended one), from 1.15 to 0.85 Kyr BP during the Medieval Climate Anomaly, and from 0.65 to 0.05 kyr BP during the Little Ice Age (LIA) are distinguished. We have considered various new regional proxy records as paleoclimatic background to evaluate and model the forcing of glacier fluctuations. Extrapolated air temperatures from our SST records have been used to calculate the required precipitation for a reasonable positive glacier mass balance during the advances. The results indicate a 50 to 80% increased accumulation (compared to the last decade) of 9500 to 14000 mm/year which is also consistent with much higher precipitations documented in our paleoclimate records for these phases. Only the advances during the LIA, which occurred with ~1.5°C lower temperatures compared to the average of the last 20 years, require significantly lower precipitation/accumulation of ~6000 mm/year. This indicates a predominant accumulation-driven forcing in this hyperhumid oceanic setting, contrasting to a general ablation-control of Holocene advances and retreat phases in many regions world-wide, especially during recent global warming.

Disentangling moisture origins in $\delta^{18}O$ tree-ring time series from Lago Argentino

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Abstract

Glacier mass balance on the eastern part of the Southern Patagonian ice sheet is predominantly influenced by precipitation variability. As the spatio-temporal availability of meteorological time-series extending back more than 50 years is scarce and humidity conditions vary largely in high mountain areas, there is a strong need for proxy data providing insight into the local and regional hydroclimatic history as well as the long-term climatic variability. The isotopic $\delta^{18}O$ signal in tree-ring cellulose is strongly influenced by soil water, which is dependent on the amount and origin of meteoric (precipitation) water (source water $\delta^{18}O$). Within this study, we combine tree-ring δ18O analysis with backward trajectory modelling to reconstruct long-term atmospheric circulation patterns and their contribution to local precipitation changes. Trajectory modelling is accomplished through applying the hybrid single particle Lagrangian integrated trajectory model 4 (HYSPLIT4), driven by gridded reanalysis data (NCEP/NCAR; ERA-Interim C). Individual trajectories are extracted from a vertical motion field based on horizontal wind components (u, v), temperature, pressure level, and surface pressure. Additionally, we focus on years with extraordinarily high/low $\delta^{18}O$ values, which are expected to reflect the strongest changes in air mass origin. This approach enables us to determine the mean annual airflow direction for the past centuries, and accordingly the availability of moisture contributing to glacier mass balance.

A history of the oscillations of Schiaparelli glacier since the Little Ice Age derived from tree-ring based moraine dating

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Abstract

Since the availability of satellite data and airborne photography, glacial mapping is facilitated, but besides historical records, information about former glacial extents are very scarce. Knowledge about prior glacial dimensions is indispensable to quantify the consequences of recent changes in surface under future climate change scenarios. Especially in remote areas which are difficult to access, historical records are rare. Dating glacier moraines offers the opportunity to derive information about the former glacial maxima and also about timing and speed of glacial oscillation. The germination date of trees on moraines can be used as a minimum age for a maximum glacier advance or the start of glacier retreat. Newly acquired tree-ring data (*Nothofagus betuloides*) from the glacier forefield of Schiaparelli Glacier is linked to previous studies from Cordillera Darwin, Tierra del Fuego. The former extend of Glacier Schiaparelli is discussed with regards to historical records. The time between stabilization of an initial soil surface and settlement of first trees ('ecesis time') was estimated by sampling 60 trees at the lateral moraine which was still glaciated in 1986 as documented by satellite data. Recolonization with trees was found to occur within 10 years, revealing that many studies overestimate this process up to 50 years. We identified three major frontal moraines with declining age towards the recent glacier tongue, dating to 1750, 1775 and 1880, respectively. Additionally, 14C ages of buried trees (1750 +/- 35 BP) in the glacier forefield located between the dated moraines and the glacier tongue suggest an advance of the glacier before 1750. Besides moraine dating, tree-rings provide a suitable climate proxy with yearly resolution. For instance, at our sampling site tree-ring width is strongly related to increasing minimum temperatures since 1900. We also applied a remote sensing approach in which almost 3000 glaciers were mapped from Landsat TM/ETM+ scenes and geomorphological evidence were used to derive the Little Ice Age maximum glacier advance. Different methods to calculate the equilibrium line altitudes (ELA) i.e., toe-to-ridge altitude (TRAM), accumulation-area-ratio (AAR), area-altitude balance ratio (AABR) were used and compared to further ELA proxies like the transient snowlines (TSL), maximum altitudes of lateral moraines and trimlines. A map of spatial distribution of the ELAs was generated by interpolating the calculated ELAs using the inverse distance weighted interpolation (IDW).

Moraine ecology and genetic diversity: A comparison of the moss colonization after glaciers retreat in Southern Patagonia

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Abstract

In recent decades, glaciers are increasingly in the focus of worldwide research interest, especially in connection with the global glacier recession and associated melt occurring since the 20th century. Many of the Fuego-Patagonian glaciers are experiencing major wasting in comparison with worldwide average rates (Pellicciotti et al., 2014). The spatial variability of the disappearance of glaciers in Patagonia varies due to different ice dynamic processes, latitude and altitude, topography and the partially decreasing snow precipitation process, that has been occurring since the Little Ice Age (Davies & Glasser, 2012). Mosses are a part of the flora in Patagonia. They are currently used as model to monitoring responses to climate change (Ochyra et al., 2008), where their limits can be altered with variations in climate and it is possible to establish relationships among the historic periods of glaciations. Thus, currently they represent limits of survival and colonization, where mosses are very successful in the places where they used to be, from wetter areas and channel banks to dry moraine detritus and crevices of rocks, on flat or sloped surfaces. Furthermore, some moss species are very sensitive to the smallest edaphic and microclimatic differences, expressed in the dominance of one species and the structure of the communities. The 3-year long German-Chilean project network GABY-VASA aims to strengthen existing research cooperation oriented to decipher the impact of the changes in the cryosphere and biosphere in the past and the future. We are using (cp)DNA sequences for the analysis of the genetic diversity and phylogeography of different moss species and how this distribution could be linked to changes in glaciers and the surroundings moraines in Southern Patagonia. Work packages include samples from Grey Glacier (Southern Patagonia Icefield) and Schiaparelli Glacier.

Dendroclimatic analysis of *Nothofagus betuloides* forests from Cordillera Darwin, Tierra del Fuego, Chile

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Abstract

We developed four new tree-ring width chronologies from *Nothofagus betuloides* forests of Cordillera Darwin, Tierra del Fuego, southernmost Chile. The purpose of this work was to estimate the influence of changes in temperature, rainfall and the Southern Annular Mode (SAM) on *Nothofagus betuloides* tree growth. Tree-ring samples were collected at Glaciar Schiaparelli valley (54º25'S, 70º54'W), and Valle de los Divorcios (54º36'S, 69º03'W), in periglacial environments of these study sites, trying to connect the dendroclimatic signal of the *Nothofagus betuloides* forests with the glacial dynamics of some of the most studied glaciers of Cordillera Darwin. We also include in our analysis data previously published: Another four *Nothofagus betuloides* tree-ring width chronologies, from study areas adjacent to Cordillera Darwin, and the isotopic composition of an ice-core record from James Ross Island, Antarctica.

We identified two main tree-growth patterns using a Principal Component Analysis (PCA): PC1 or eastern tree-growth mode, and PC2 or western tree-growth mode. PC1 showed significant negative correlations with summer rainfall, temperature and SAM index, while PC2 presented significant positive correlations with air temperature, rainfall and SAM index. The comparison of the tree-growth modes with the James Ross Island record showed similar results.

Taking advantage of this good correlation between tree-growth and climate variability, we conducted a preliminary analysis on the relationship between variations on the length of well-studied glaciers such as Marinelli and Schiaparelli, climate index mimicking glacier mass balance, and tree-growth trends. Our results show that starting in 1980 there is a constant negative mass balance, a marked decrease in glacier lengths and a decreasing trend in tree growth represented by the eastern tree-growth pattern.

Droughts as triggers of *Nothofagus pumilio* growth decline in northern Patagonia, Argentina.

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Abstract

Understanding the influence of climatic variations on forest decline is a major challenge for scientists investigating global changes. Although reductions in tree growth have previously been associated with forest decline, comprehensive efforts to understand these relationships are rare. Based on ring-width variations, we determine the influence of climatic fluctuations on the onset and temporal evolution of *Nothofagus pumilio* growth decline in the Patagonian Andes. We sampled 11 sites showing crown dieback symptoms. Regional patterns of Basal Area Increment (BAI) were derived from 294 Nothofagus trees in a 500-km latitudinal transect along the forest-steppe ecotone in northern Patagonia. Two BAI patterns show sustained negative trends over the last three to six decades. Tipping points in growth trends are associated with two extreme dry-warm climate events in spring-summer of 1942-1943 / 1943-1944 / 1944-1945 and 1978-1979. Both severe droughts were preceded by up to 10 years of wet periods that promoted above-average tree growth. We concluded that severe droughts occurring after wet periods trigger the decline of large, dominant *N. pumilio* trees with high rates of growth. The coincidence between major changes in regional growth with two of the most severe droughts in the instrumental records shows that climatic variations over northern Patagonia synchronize the onset of forest decline at a regional scale. As these dry-mesic *N. pumilio* sites will face more severe droughts in the 21st century as suggested by future climate scenarios, the areas affected by forest decline would increase substantially.

Poster #14

Palaeoenvironmental changes in southern Patagonia inferred from the Lake Gemelas Este record

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Abstract

Multiple climate proxies from one site can complement each other and thus provide more comprehensive paleoclimate records not available from a single proxy. Patagonia is a key area for understanding climate change in the Southern Hemisphere. In particular, the present-day steppe-forest ecotone is considered very sensitive to climate perturbations. Lake Gemelas Este (49º 23.1'S - 72º 53.9'W, Santa Cruz, Argentina), provided a short core suitable for multi-proxy studies at the eastern flank of the Andes. XRF scanning data, stable isotope ratios of sedimentary organic matter, and diatom assemblages were combined and reflect past changes of primary productivity and biogeochemical cycling in the lake. The core was subsampled every 1 cm for diatom and isotopes analyses. We analysed stable isotopes of organic carbon (δ13Corg) and nitrogen (δ15N) and diatom assemblages on the sediment core. Diatom analysis was performed following standard techniques for species compositional changes and quantitative studies. Throughout the studied sequence, concordant variations were observed in the diatom assemblages and the isotopes analyses. Minima in diatom abundances were related to volcanic activity, evidenced by the presence of tephra in the sedimentary sequence. Moreover, diatom species composition before and after the tephra is different. The occurrence of the new species in our record, which ecological requirements are not known, and still incomplete training sets for the study area are challenges for an accurate interpretation of the diatom record.

Poster #15

The project OXICLIM – synthesis of oxygen isotope proxies for climate reconstruction in southern Patagonia

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Abstract

OXICLIM is a recently launched Argentinean-German scientific initiative intended to synthesize terrestrial climate archives in the area of Los Glaciares national park in Argentinean Patagonia. In particular, oxygen isotope proxies from tree-rings are compared with those of lake sediment along a humidity gradient from the humid Andean *Nothofagus* forest to the Patagonian steppe. The aim is to provide quantitative climate reconstructions using transfer functions. In the lakes, chironomid head capsules and aquatic cellulose will be used as proxies of the oxygen isotope signal of the lake water. The lake water oxygen isotope composition itself is determined by hydrological constrains, such as the lake water balance and the intensity of the Southern Westerlies. The oxygen isotope composition of tree-rings will be analysed from tree rings of *Nothofagus pumilio* taken with increment corers. The trees' oxygen isotope composition is supposed to be strongly determined by water availability and isotopic composition of the rainwater. Combining both archives, tree-rings and lake sediments, is a novel approach that best can be tested in areas with strong hydrological gradients, such as the eastern flank of the Patagonian Andes.

Poster #16

Stable isotopic analysis of a late-Holocene peat sequence from Patagonia

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Abstract

Variability in the Southern Annular Mode, including the dominance, strength and position of the southern Westerlies influence the climate of southern South America and are likely to imprint upon the stable-isotopic composition of precipitation across southern Patagonia. In this study we explore the potential of Sphagnum magellanicum-dominated ombrotrophic peatlands as an archive of past changes in atmospheric circulation and hydroclimate. Through the carbon, oxygen and hydrogen stable-isotope analysis of Sphagnum α-cellulose we present a record of isotopic variability for Tierra Australis (S54° 36’ 58.6”, W67° 46’ 14.4” 127m.a.s.l.) covering the last two millennia. Our preliminary interpretation of this record is supported through modern process-based studies and testate amoeba/plant macrofossil analyses to reconstruct water-table depth

Poster #17

Establishment of *Nothofagus pumilio* at upper treelines across precipitation gradients. Part II: The Southern Patagonian Andes

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Abstract

Trees at upper treelines are exposed to more extreme environmental conditions than those at lower elevations. Climate changes at the upper treeline facilitate the establishment or intensify the mortality of trees and, consequently, affect species distributions. The structure and density of individuals of *Nothofagus pumilio* above the upper treeline, together with their temporal patterns of establishment, were determined in three sites located along a west-east precipitation gradient across the Southern Patagonian Andes. This work complements previous studies conducted in the Northern Patagonian Andes (Part I). Patterns of tree establishment in the Southern Andes were compared to regional variations in temperature and precipitation, as well as to the Antarctic Oscillation (AAO or SAM) index, the atmospheric circulation modes related to climate variability in Southern Patagonia. Mesic and dry sites along the moisture gradient have a lower density of newly established trees; however, individuals show larger basal diameters, heights, and number of branches than those established in humid sites. In wet areas, the high density of individuals reflects the higher rates of *N. pumilio* establishment and survival. At drier treelines, the low snow persistence, associated with longer growing seasons, appears to be related to the larger size of individuals. At all sites, patterns of tree establishment are characterized by a gradual increase in recruitment starting in the mid-1970s followed by abundant establishment during the 1980s. This marked increase in tree establishment above the treeline is concurrent with a period of above-average summer temperatures starting in the year 1977. Contrary to patterns of establishment documented in Northern Patagonia, new recruitment in the Southern Andes has shown a constant rate of tree establishment to present. Whereas above treeline establishment in northern Patagonia is largely modulated by changes in the phase of the Pacific Decadal Oscillation, the stable rate of recruitment in the Southern Andes since 1977 to present, appears to be related to the persistent positive trend recorded in AAO during the past decades.

Moisture transport mechanisms in Patagonia

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Abstract

The southern tip of South America is thought to be one of the wettest regions on Earth, and both observations and climate model simulations consistently indicate that the precipitation amounts along Patagonia's west coast are far above the mid-latitude average. Such precipitation amounts are usually expected in tropical regions, where the column integrated water vapor content is high. Large-scale baroclinic eddies are the main meridional water vapor transport mechanism and link the tropical atmospheric water reservoir with the dryer high- and mid-latitudes. Even though these eddies intermittently trigger moist atmospheric streamers, which reach the west coast of Patagonia, this only partly explains the precipitation amounts in Patagonia. Here we analyse newly available in-situ data, radiosoundings and remote sensing products to better understand the processes contributing to this phenomenon. We also use simple scaling arguments to estimate potential precipitation amounts in this region.

Comparison of modeled surface energy and mass balance variations of Grey and Tyndall Glacier at the Southern Patagonia Icefield

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Abstract

Despite the overall glacier retreat and thinning of most Patagonian glaciers, diverse responses and a recent increase of mass loss have been observed. In this context, the influence of surface mass balance processes on recent glacier response still needs refinement. We therefore quantify and compare surface energy-fluxes and mass balance processes of the two neighboring glaciers, Tyndall and Grey at the Southern Patagonia Icefield.

The COupled Snow and Ice energy and MAss balance model COSIMA is applied to assess recent surface energy and mass balance variability with a high temporal and spatial resolution for the period 2000 to 2016. COSIMA is driven by 6-hourly atmospheric data derived from ERA-Interim reanalysis data. Surface air temperature is statistically downscaled using quantile mapping based on automatic weather station data. Incoming shortwave radiation is derived from a radiation model that computes clear-sky direct and diffuse shortwave radiation. Furthermore, MODIS/Terra Snow Cover Daily L3 Global 500 m Grid (MOD10A1) cloud mask data is used to cover the spatial distribution of cloud cover related variability in solar radiation. High resolution precipitation fields are obtained by using an analytical orographic precipitation model.

The evaluation of this study focuses on the applicability of COSIMA and the chosen downscaling methods for Patagonian glaciers as well as on a detailed comparison of local climate conditions, surface energy balance components and recent surface changes between both study sites.

The Energy Balance of Chilean Glaciers

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Abstract

Chile is hosting glaciers in a large range of latitudes: From 18° S in the Atacama Desert to 55° S on Tierra del Fuego Island. Glaciers are predominantly thinning and retreating along this whole range of latitudes. The thinning and retreat are most probably related to regional changes in climate. Projections of future climate in Chile vary strongly depending on the latitude that is the climate/glaciological zone of the glacier. Therefore, a sound quantification of energy exchange between atmosphere and glaciers in every zone is necessary to make reliable predictions about future glacier behavior. We present direct measurements and modeling of the surface energy balances of six Chilean glaciers which are located in three different glaciological zones. We compare how relevant climate parameters vary from one glaciological zone to another and show how these parameters influence the different components of the surface energy balance of the glaciers. During summer (January to March) the net solar radiation is the most important source of energy for all the glaciers. The net long wave radiation is a sink of energy for all the glaciers, with much higher absolute value in the dryer central zone and with less importance in the humid Patagonia. The sensible heat flux during summer is an important source of energy as well. The latent heat flux changes from energy sink in the Central Andes to source of energy in Patagonia. To be able to make predictions of future mass loss of Chilean glaciers in the different glaciological zones, models have to be able to reproduce these systematic features revealed by our study.

Poster #18

Contrasting precipitation and temperature patterns in the Southern Andes related to the recent shift in the Antarctic Oscillation Index

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Abstract

Marked changes in the Antarctic Oscillation Index (SAM) have recently been recorded. Following persistent positive trends since early 2014, an abrupt shift to negative SAM values occurred in October-November 2016 and persisted to early February 2017. Based on the SAM-Marshal Index, January values varied from +3.13 in 2016 to -1.12 in 2017. This contrasting shift provides a good opportunity to determine the temperature and precipitation variations across southern Patagonia associated with SAM phases. We recorded substantial changes in January temperatures between 2016 (warm) and 2017 (cool) over the Andes between 45° and 49°S. At Cochrane, a difference of 3.9°C was recorded between mean January temperatures in 2016 and 2017. Differences were lower to the south (0.6° and 0.2°C at Punta Arenas and Ushuaia, respectively) and in eastern directions, where opposite trends between January 2016 (cool) and 2017 (warm) were recorded at San Julian (-0.4°C) and C. Rivadavia (-0.3°C) on the Atlantic coast. Recorded changes in precipitation were also larger across the southern Andes. Extremely drier conditions in January 2016 contrast with abundant rainfalls during January 2017. On the eastern side of the Southern Patagonian Icefield, rainfall in January 2017 was ten times greater than in January 2016. At C. Masilla and Villa O'Higgins, January rainfalls varied from 5.6 to 110.1mm and 7.9 to 108.3 mm, for January 2016 and 2017, respectively. This rainfall pattern extended north at least to 46°S, where total January precipitations at Balmaceda of 0.2mm in 2016 contrast with 57 mm in 2017. These changes in precipitation decreased comparatively to the south. At Puerto Natales, January precipitation in 2017 (38.2 mm) was approximately three times larger than during the same month in 2016 (12.5 mm) and less than double farther south at Puerto Williams in Tierra del Fuego (51.6 and 90.6 in January 2016 and 2017, respectively). We emphasize the need to document the temperature and precipitation changes related to SAM across southern South America to properly identify the spatial patterns of climate variability associated with this major mode of climate variability at high latitudes in the Southern Hemisphere.

Atmospheric Sciences **Poster Presentations**

Poster #19

Regional Climate Models performance by precipitation and temperature analysis in Fuego – Patagonia.

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3-Universidad de Concepción, Chile.

Abstract

There is a growing interest in understanding how the current climate changes will affect the Earth system. In this regard, numerical modelling of the atmosphere and climate system is a powerful tool to forecast future conditions. The low resolution of General Circulation Models (GCMs), makes them unsuitable for the specific case of Chile, a long and narrow country with complex topography, with the Andes mountain range extending from north to south. In this case, in order to better understand the climate system, it is necessary to apply a higher resolution Regional Climate Model (RCM) nested into a GCM.

Two main studies have been published in Chile regarding future climate variability. The first was carried out in 2006 by the Department of Geophysics (DGF) of Chile University, which used the regional model PRECIS coupled to the global HadCM3 model. The second study was carried out by Chile's Meteorological Directorate (DMC) in 2014, using the WRF model coupled to the global model MIROC5. In both studies an increase of atmospheric temperatures is observed over Fuego-Patagonia, but smaller in magnitude than in central Chile due to the lower altitude of the Andes, the ocean influence and the westerlies circulation. In the case of precipitation, future trends suggest an increase in Fuego-Patagonia, contrary to the decrease observed in the central and southern areas of the country. A hindcast analysis of the DMC (2014) model results is performed for the period 1970-2000, with the objective of understanding climate variability at Brunswick Peninsula, located in southwestern Patagonia.

Poster #20

Lagrangian Moisture Source Detection of the Southern Patagonia Icefield

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Abstract

The moisture source of the Southern Patagonia Icefield (SPI) and its transport is not yet fully understood. It has a large impact on the stable isotope composition of the SPI and is hardly quantifiable from observations.

This study presents a verified Lagrangian moisture source detection technique applied on the SPI. The kinematic backward trajectory calculations are based on the European Centre for Medium-Range Weather Forecasts reanalysis data (ERA-Interim) from January 1979 to December 2016. Besides a whole ERA-Interim climatology of the moisture source variability with regards to teleconnections, seasons, and extreme precipitation events, the moisture transport in the atmosphere is depicted as well.

The dominant sources of water vapor are found in the Pacific Ocean between 80 °W to 170 °W and 30 °S to 60 °S with two local maximums. One is located just off the coastline of Patagonia and the other at the subtropical Pacific at approximately 35 °S, 100 °W where advection of moist air by the prevailing westerlies play a major role. A significantly smaller moisture source region is identified at the southwest Atlantic Ocean at approximately 50 °S, 60 °W where an anticyclonic flow transports the moisture to the SPI. Teleconnections of the moisture sources with regards to

El-Nino Southern Oscillation (ENSO) are not visible. Seasonal variabilities are found. In austral winter months the moisture sources shift eastward. High precipitation months indicate more long-range transport and a strengthening of the atmospheric river. By contrast low precipitation months reveal a dislocation of the atmospheric river.

additionally as an oral on Tuesday, July 18th - Poster #21

Implementing a Parametrization for Snow Drift on Mocho Glacier (40°S, Chile)

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Abstract

Snow drift is a determining factor for the accumulation patterns on glaciers and therefore also for their distributed surface mass balance (SMB) patterns. In this work, two terrain-based wind drift parameters (wind shelter and curvature) were examined and related to accumulation factors which were implemented in a SMB model for Mocho Glacier (40°S, Chilean Lake District) in order to reproduce end of summer snow patterns as they are seen on satellite images. It is assumed that freshly fallen snow is eroded on sites that are wind exposed or have a convex curvature, and that additional snow is accumulated in places that are wind sheltered or have a concave curvature. The wind shelter and curvature grids were calculated on the base of a Digital Elevation Model (DEM). When examining the grids of wind shelter and curvature, good correlation to the remaining snow on end of summer satellite images is seen: on a large percentage of the glacier's area snow was on the surface where the parameters indicate increased accumulation, and ice was on glacier surface where erosion due to the parameters would take place. Including accumulation factors related to wind shelter and curvature improved the simulated end of summer snow patterns in several regions, and the improvement was clearer for the curvature related accumulation factor.

Atmospheric Sciences **Poster Presentations**

Poster #22

Low-cost autonomous stations for measuring glacier ablation and meteorological parameters on Patagonian glaciers

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5-Universidad de Magallanes, Chile

Abstract

We propose new methods for monitoring glaciers through a network of low-cost sensors based on a model of situational awareness. Glaciers play a very important role in the planet's climate, and changes in their behavior can trigger climatic events, change the climate, and affect oceans and ecosystems. Therefore, efforts to monitor the behavior of the planet's ice have been increasingly needed to better understand how glaciers interact with the atmosphere and oceans. Technological advancements have made computers increasingly transparent in our daily activities, where multiple devices are wired remotely and wirelessly to provide us with information. Therefore, the application of such concepts can be used for the monitoring of glaciers. Our work focus on the development of low-cost open source equipments for recording meteorological parameters and glacier melting rates, allowing an unprecedented spatial distribution of these measurements. Such approach would enable the high resolution record of the melting rate of glaciers, helping to understand their relation with specific meteorological events. The sensor network we propose here is based on the idea of an incremental advance that began with the design and implementation of the two first Automatic Weather Stations (AWSs). We developed these AWSs using the Arduino prototype platform to integrate low-cost sensors for measurement of air temperature, atmospheric pressure, air humidity, wind direction, wind speed, snow accumulation, ice temperature, and solar radiation. For the tripod, we used carbon fiber recycled from broken windsurf masts. The feet of the tripod have stainless steel structures similar to ice crampons, used to adhere to ice surfaces. We record the environmental variables every minute and store it on a MicroSD memory card. The two AWSs were installed on Schiaparelli and Grey glaciers in September 2015. For validating the sensors used in the low-cost station, we are evaluating the statistical correlation of each meteorological parameter with its corresponding recorded by a Campbell Scientific AWS we installed on the surface of Schiaparelli glacier in 2013. During the presentation we will show the cross-correlations and RMS errors resulting from this analysis. Another key component to increase the accuracy of traditional mass balance measurements is the electronic ablation station. It consists of pvc pipes with RFID

tags installed every 15 cm, and a datalogger that records the moment when the RFID reader crosses every tag. In October 2016, we install two electronic ablation stations on Schiaparelli glacier and two more on Grey glacier. In this way, we hope to identify specific local meteorological events that most influence the melting processes on glacier surfaces.

Glacier Mass Balance **Oral Presentations**

Surface altitude change assessment by means of DGPS measurements at Grey and Schiaparelli glaciers

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Abstract

Geometry changes of glaciers represent indicators of both the impact and responses of ice to climate variability and correlate their signature with other important processes of glacier mass balance and ice dynamics. Surface altitude variability is a main information for characterizing the negative or positive ice mass balance. Since mid-2013, differential GPS (dGPS) surveys have been carried out annually at the terminus zone of Grey and Schiaparelli glaciers, using a base and rover stations composed of dual frequency Leica Viva 15 receivers to localize the positions of ablation stakes used for mass balance monitoring and to record the surface elevation of the glacier. These data have been surveyed with cm-level accuracy based on the use of Real Time Kinematic (RTK) method. As a result data clouds of x,y,z processed positions of two different epochs are obtained. These two data clouds are compared using free open source software where data point separation between both epochs can be parameterized to obtain dh/dt variations at the ablation area of Grey and Schiaparelli glaciers. Spatial and elevation distribution of dh/dt values are analyzed for each glacier.

Glacier Mass Balance **Oral Presentations**

Changes in calving glaciers and glacier-lake interaction in the Southern Patagonia Icefield

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Abstract

Patagonia Icefields are rapidly losing mass at one of the greatest rates of specific mass loss in the world. The mass loss is driven by negative surface mass balances and accelerated ice discharge from calving glaciers. The increase in discharge is important particularly for rapid retreat and thinning of calving glaciers. Despite their importance to understand the future mass change of the icefields, processes occurring at the calving front are not well studied and understood in Patagonia. To quantify the changes in calving glaciers and understand better the mechanisms driving the rapid changes, we performed field and satellite based observations in the Southern Patagonia Icefield. Satellite data were analyzed to measure the ice speed and frontal positions of 28 major calving glaciers since the 1980s. More detailed analyses were performed on Glaciar Perito Moreno to investigate the seasonal frontal variations. Field measurements were carried out on the ice and in the lakes near the fronts of Glaciar Perito Moreno, Upsala, and Viedma. Our field work included measurements of ice flow speed, lakewater temperature, turbidity, lake bathymetry, water sampling and isotope analysis. We present the results of these research activities in Argentina and introduce more recent research project currently being carried out at Glaciar Grey in Chile.

Mapping glacier thickness in Patagonia using a mass conservation approach

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Abstract

Satellite remote sensing based on optical or radar instruments has enable us to measure glacier-wide surface velocities as well as changes both in glacier extent and surface elevation with good coverage worldwide. Yet, for the large majority of all glaciers and ice caps, there is in fact no information on how thick the ice cover is. Any attempt to predict glacier demise under climatic warming and to estimate the future contribution to sea-level rise is limited as long as the glacier thickness is not well constrained. Moreover, the poor knowledge of the bed topography inhibits the applicability of ice-flow models which could help to understand dominant processes controlling the ice-front evolution of marine-terminating glaciers. As it is impractical to measure ice thicknesses on many glaciers, reconstruction approaches have been forwarded that can infer thickness fields from available geometric, climatic and ice-flow information. Here, we presented a mass-conserving reconstruction approach to infer ice-thickness fields with prior knowledge on source and sink terms in the mass budget.

The first-step reconstruction is aimed at glaciers for which not much information is available. Input requirements for this first step comprise geometric and climatic variables similar to other reconstruction approaches that have successfully been applied to glaciers world-wide. Available thickness measurements are readily assimilated. The performance of the approach has been assessed for various glacier geometries, including marine and land-terminated glaciers as well as ice caps. Here, we apply the reconstruction to glaciers draining the Patagonian ice fields. The inferred thickness field is compared to a recent reconstruction relying on geometric information only. The thickness map is provided together with an error-estimate map that stems from a formal propagation of input uncertainties through the underlying equations.

Glacier Mass Balance **Oral Presentations**

Evolution and fate of remnant ice detached from Marinelli Glacier, Cordillera Darwin

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Abstract

Under global warming conditions glaciers not only reduce in area and volume but can also suffer fragmentation into separate ice bodies. When fragmentation occurs within the ablation area, the detached ice is no longer nourished from the accumulation area and rapidly loses mass until it eventually becomes extinct, enhanced by positive feedback mechanisms such as area scaling and albedo effects. Marinelli Glacier is the largest glacier of the Cordillera Darwin icefield (CDI) in Tierra del Fuego, with a length of 21 km and an area of 133 km^2 in 2011 (Bown et al., 2014). It has a tidewater front, draining to the north, and shows the greatest frontal retreat of CDI, having lost 15 km between 1913 and 2011, with a relatively stable front thereafter (2011-2017). Until about 1984 Marinelli glacier had a land-terminating tongue immediately west of the main terminus, with a length of 3 km and a mean width of 1 km. After 1984 this western tongue became detached from the main Marinelli Glacier, losing its accumulation source and becoming a remnant ice body. By 2017 this remnant ice body has lost 75% of its area, reduced to a length of 1.5 km and a mean width of 0.5 km. We apply a simple temperature-index model incorporating atmospheric temperature, solar radiation and glacier albedo, and also winter snow accumulation, in order to model the future evolution of the detached ice. Glacier fragmentation is a very effective means for amplifying glacier loss, and is not normally incorporated in glacier evolution models

Glacier Mass Balance **Oral Presentations**

Recent behavior of the Amalia and Grey glaciers and its relation with a possible activity of the Reclus volcano and the local environmental conditions

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Abstract

A particularly warm period has been occurring since the end of the Little Ice Age (LIA), since the mid-nineteenth century, as a result of the natural increase of solar radiation from the Wolf, Spörer, Maunder and Dalton minimums, and the warming produced by the anthropogenic increase of greenhouse gases (IPCC, 2013) increasing the reduction of the different elements of the cryosphere. The possibility of influencing activity of the Reclus volcano on the dynamics of glaciers is ruled out. For this reason, the dynamics and behavior of the Amalia (50°55'S 73°37'W) and Grey (50°57'S 73°15'W) glaciers along with their environment located in Southern Patagonian Ice Field (SPIF) are investigated and described.

The study variables used for this research are LANDSAT images and aerial photographs, geomorphological and glaciological description of the zone, contrast of the available meteorology, also analysis of shallow soil temperatures adjacent to the glaciers in the area of the Reclus volcano, and finally obtaining a model of mass balance at the base of the Amalia glacier.

With the satellite imagery process, updated maps of the frontal glaciers were obtained with an average rate of 82 m/year in the Amalia glacier between 1907 and 2016, and 41 m/year in the Grey Glacier between 1930 and 2016. Geomorphology and glaciology describe a very dynamic situation resulting from the retreat of glaciers, transport and deposit of material, water flows and soil erosion. The limited meteorological information provided by remote stations close to the glaciers over the last two and three years indicate that as much as the air temperature with an annual average of 6.8 °C and precipitation with a monthly average of 213 mm is higher in the area of the Amalia glacier west of SPHF and slightly decreases to the east in the area of the Grey Glacier. In the search for soil temperatures anomalies in the area of the Reclus volcano that could contribute to the ablation of glaciers, shallow temperatures are measured at different points near the Amalia glacier in the west and Grey in the east, discarding this last option because the trend of the variation of the temperature is only of the air. The mass balance model is applied at the base of the Amalia glacier from the melting of ice by the geothermal heat flux and the thermal melting of friction at the base of the glacier.

Glacier Mass Balance **Oral Presentations**

Recent work on surface energy and mass balance modelling using meteorological and glaciological observations at Schiaparelli Glacier, Cordillera Darwin

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Abstract

This study gives an overview of the recent work on meteorological and glaciological observations, and on surface energy and mass balance modelling of Schiaparelli Glacier at the Cordillera Darwin as part of the Chilean-German GABY-VASA project (Responses of Glaciers, Biosphere and Hydrology to Climate Variability and Climate Change across the Southern Andes).

Meteorological and glaciological observations are carried out since September 2015, including one automatic weather station (AWS), distributed air temperature and solar radiation measurements, time lapse images of the calving front, and ablation measurements, both by ablations stakes and time lapse camera. We further show preliminary results of applying the COupled Snow and Ice energy and MAss balance model COSIMA to Schiaparelli. COSIMA is driven by hourly AWS data for the ablation area with a spatial resolution of 200 m for model calibration. Additional model runs forced with downscaled ERA-Interim reanalysis data are compared to evaluate the applicability of reanalysis data for glacier-wide and long-term COSIMA runs.

At the final stage of the project, we subsequently aiming at the quantification and comparison of energy-fluxes and mass balance processes at the glacier surface and subsurface between selected sites at the Southern Patagonia Icefield and Cordillera Darwin.

Glacier Mass Balance **Oral Presentations**

Evolution of Gran Campo Nevado - The journey of a Patagonian ice field through time

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[withdrawn]

oral contribution Monday, July, 17th & Poster #23

Air temperature differences and melt estimated from a weather station network in the South Patagonian Icefield

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Abstract

In the South Patagonia Icefield (SPI), glaciers are currently shrinking in response to mid-tropospheric warming. These glaciers are mainly sensitive to temperature change, because ablation is dominated by melt. However, orographic effects can play an important role in ablation even for different glaciers at the same latitude. This is particularly the case for the Southern Andes where the west side is wet and the east side is relatively dry. Considering that current climate models typically have resolutions of ~50 km and therefore fail to capture the finer, catchment-scale details of the terrain, on-glacier observations are necessary to avoid biases in the modelling of the glacier response. A weather station network recently installed by the Centro de Estudios Científicos (CECs) within a project of the National Water Office of Chile (DGA) made it possible to characterize the air temperature differences across a longitudinal profile at around 48° 45' S. This analysis shows that differences in air temperature behaviour exist between glaciers that are closely located on both sides of the SPI. We also used these air temperature data to drive a first-order melt model for the ablation season 2015-2016, showing that melt on the eastern side of the SPI is greater in magnitude than melt on the western side for comparable elevations. On-glacier data from these weather stations will allow validation and downscaling of data from climate models to conduct modelling studies to define the present and future responses of glaciers in the SPI. This work is financed by CONICYT, Doctoral Fellowship (CB).

Poster #24

Ice-flux and regional climate modeling to constrain the surface mass balance and ice discharge of San Rafael Glacier, northern Patagonia

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Abstract

We simulate the ice dynamics of the San Rafael Glacier located in the Northern Patagonia Icefield (46.7ºS/73.5ºW). The glacier topography and ice thickness are obtained by high resolution airborne gravity and GPS measurements. The model is initialized using an inverse method to infer the basal friction coefficient from surface velocity estimations given by previous studies based on multiple synthetic aperture radar and optical satellite data collected between 1994 and 2014. Low values of basal shear stress (<100 kPa) are obtained at the front of the glacier and are in agreement with values from other ice streams. These values are reasonable considering the high surface velocities in this zone (up to 7.5 km/a). The modelled ice flow results suggest that the horizontal velocities are quasi-independent from depth in the lowest zone of the glacier.

We force the 3D full-Stokes Elmer-Ice model based on a specific surface mass balance function for the San Rafael Glacier given by previous studies. We use geodetic elevation changes during the study period (2000-2012) and analyze the influence of different functions on the glacier dynamics, ice discharge and mass balance. The analysis suggests that the average SMB for the entire glacier is 0.08±0.05 Gt/a and that previous SMB estimations for San Rafael Glacier significantly overestimated the accumulation. The ice discharge is estimated at -0.98±0.38 Gt/a.

In order to assess a more accurate SMB distribution at the glacier surface, we modelled the distributed surface mass balance over the last decade using the regional circulation model (MAR) forced with the Era-Interim and NCEP-NCAR reanalysis data. With these simulations, we aim to improve our understanding of the causes for the San Rafael Glacier's wastage.

Poster #25

Geodetic Mass Balance of the North Patagonian Icefield (46 - 47°S) during 2000-2012: Comparison of two independent estimates based on satellite data.

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Abstract

We compare two different spaceborne estimates of the rate of elevation change and geodetic mass balance of the North Patagonian Icefield (NPI) between 2000 (3856 km²) and 2012 (3740 km²). The first estimate is obtained by a simple differentiation of the shuttle radar topographic mission (SRTM) digital elevation model (DEM) from February 2000 and a SPOT5 DEM from March 2012. The second one is deduced by fitting a linear elevation trend over 118 DEMs calculated from Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) stereo-images acquired between 2000 and 2012. Both methodologies led to similar and strongly negative icefield-wide mass balances of -1.02±0.21 and -1.06±0.14 m w.e. yr^{-1} respectively. Both methods reveal contrasted glacier responses with individual glacier mass balances ranging from -0.15 to -2.30 m w.e. yr^{-1} (ASTER method). Estimates agree within error bars, except for glaciers poorly sampled in the SPOT5 DEM due to clouds. Importantly, our study confirms the lack of penetration of the C-Band SRTM radar signal into the Patagonian firn except for a small region (less than 1% of the total area) above 2900 m a.s.l. A strong advantage of the ASTER method is that it relies on freely available data and could thus be extended to other glaciated areas.

Significant mass loss recorded for Glaciar Bahía del Diablo, Vega Island, Antarctic Peninsula

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Abstract

During the last two winters, the north-eastern Antarctic Peninsula experienced a lack of precipitation compared to previous years. This condition led to very negative mass balances in both glaciological years for Glaciar Bahía del Diablo.

The mass balances for the last two years yielded -380 mm w. eq. (2016/17) and -605 mm w. eq. (2015/16), being the latter the highest loss registered since the mass balance program began. This very low mass balance records for Bahía del Diablo Glacier are a direct consequence of the low annual precipitation nearby the glacier. Precipitation of approximately 200 mm water equivalent less than usual for each year was measured, which represents 60% of the total precipitation at sea level and 40% of the total precipitation at 650 m a.s.l.

After 6 years of positive or near zero mass balances, high mass loss was determined, also despite mean temperatures for both summers were not between the warmest of the series. As mean summer temperature is directly linked to the glacier mass balance, warm seasons favored the negative mass balances and low annual precipitation increased the mass loss.

While mass loss during the glaciological year 2016/17 was in accordance with measurements in South Shetland Islands and Patagonia, the period 2015/16 has had an opposite behavior. On the north-eastern Antarctic Peninsula, the annual precipitation was very low with significant mass loss for Glaciar Bahía del Diablo, while in South Shetland Islands and Patagonia glaciers have gained or not lost mass, with a 2015 winter precipitation high.

Climate impact on Baranowski Glacier and its reaction to hydrological conditions (King George Island, W Antarctica)

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Abstract

Ice caps covering King George Island are very sensitive to climatic fluctuations. The most important factors relating to the decrease in the glaciers' area is the rise in the mean annual air temperature and precipitations. However, in recent years, regional climate cooling has been observed. Recession of Baranowski Glacier has been visible since 1979 and the specific surface area of deglaciation between 1979 and 2015 is equal to 0.73 km^2. This area is characterized by several proglacial lakes and riverbeds. Most creeks run only during intense rainfall or snow melt after winter, while Fosa and Siodlo creeks are more stable with water flow throughout the summer season. Nevertheless, the differences in the intensity of the bedload transport between these two creeks have been observed and calculated. It can be explained by the lower stage of forming of the trough of Siodlo Creek which is associated with less armoring. Moreover, the relation between bedload transport, the rapid outflow and high water discharge have indicated hysteresis in both creeks. The rate of increase of bedload in Fosa Creek was greater than of water discharge and the bedload peaked first. We suggest that this phenomenon appears as the bed material of Fosa Creek was poorly sorted, whereas in Siodlo Creek, it was moderately sorted. This indicates that the bed material in Siodlo Creek should be more easily transported, as the trough is at a lower stage of forming and easily reaches the erosion process in which the water discharge plays the most important role.

Poster #26

Effects of clouds on the energy balance of the Antarctic Peninsula Ice Sheet

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Abstract

Clouds play a key role in the energy balance of the atmosphere due to their radiative effects and have a critical influence on the radiation budget of ice sheets and glaciers; they cause a warming effect (by absorption and emission of longwave radiation) or cooling effect (by reducing the downwelling shortwave radiation) at the surface. Here we concentrate on the Antarctic Peninsula, where changes in the glacier system have been observed: Disintegration of ice shelves, acceleration and thinning of glaciers, variations in the limits between glacier facies and retreat of glacier fronts. However, rising surface air and ocean temperatures, as well as increased snow fall in some regions, are also known with trends linked to changes in atmospheric circulation. Hence, a better understanding of the processes and mechanisms leading to such changes is required, particularly the role of clouds. Preliminary retrievals of satellite-derived cloud top properties and microphysics in the Antarctic Peninsula will be presented. The data are being analyzed to test parameterizations in the Polar Weather Research and Forecasting (PWRF) model. This is aimed to ultimately enhance our understanding of how variations in the cloud cover and properties impact the energy balance on the Antarctic Peninsula at a regional scale.

Poster #27

40 year firn core record from the Schanz-Schneider glaciers divide, Ellsworth Mountains, Antarctica

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Abstract

The Ellsworth mountain region in West Antarctica is located at a key location to study the recent climate shift detected on some parts of the continent. On one side, the West Antarctic Ice Sheet is rapidly warming especially in its coastal margin, while East Antarctic seems to have more stable conditions and even cooling at some locations. During two campaigns in the austral spring of 2014 and 2015, several firn cores were retrieved from this area. The most interesting results were observed at the glacier divide of the Schanz and Schneider, which flows into the Union glacier and finally tributes the Filchner-Ronne ice shelf. Stable water isotope analysis of the cores shows a clear seasonality, allowing us to propose an age model of the firn up to 20 m depth, containing the accumulation of the last 40 years. This model was confirmed by chemical species markers like oxygen peroxide and MSA. The isotope profiles show no significant trend for the last four decades, most likely reflecting a stable mean annual air temperature for the time period covered. However, a negative trend of about 4.4 kg m^{-2} a^{-1} on the accumulation is observed (p level$<$0.05), which implies a reduction of around 50% of the local accumulation. We propose that this region should be observed into more detail, as this location represents the border between a warming west ice sheet and a cooler east Antarctica.

Poster #28

High-resolution isotope-geochemical records of firn cores from the northern Antarctic Peninsula as tools for studying climate variability

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Abstract

The Antarctic Peninsula is well known to be affected by recent atmospheric and oceanic warming. However, lacking long-term and in-situ meteorological observations complicate extrapolations to the sub-regional scale. Since 2008 we have recovered several up to 20 m long firn cores from the ice cap of Plateau Laclavere on the northern tip of the Antarctic Peninsula for isotope-geochemical and glaciological investigations.

Here we show that the stable water isotope composition of firn cores from the northern Antarctic Peninsula can reveal information on the variability of meteorological parameters such as air temperature on a sub-regional scale with high temporal (seasonal) resolution. Moreover, high-resolution density profiles of firn cores allow to determine accumulation rates.

We demonstrate that the relationship between firn core stable water isotopes and air temperatures varies between seasons due to the seasonal variability of oceanic conditions, in particular of sea ice extent that in turn is associated with variations of the Southern Annular Mode (SAM). Years with large sea ice extent in winter (negative SAM anomaly) facilitate the development of an inversion layer in the lower troposphere along the western side of the northern Antarctic Peninsula. Taking this phenomenon into account, firn core stable water isotopes reveal a slight cooling tendency of mean annual air temperatures at the study site with an approximate rate of -0.33°C y^{-1} between 2008 and 2014. In addition, we found accumulation rates on Plateau Laclavere to exhibit a high year-to-year variability ranging between 1060 kg m^{-2} y^{-1} and 2470 kg m^{-2} y^{-1} from 2008 to 2014.

Oral contribution, Tuesday, July, 17th 2017

Changes in glacier dynamics and mass budgets of the Antarctic Peninsula

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Abstract

The Antarctic Peninsula is currently undergoing considerable climatic and glaciological changes. Widespread glacier retreat and surface lowering has been reported. Several ice shelves have disintegrated or considerably retreated. Subsequently, glacier acceleration and mass loss have been reported for the Prince-Gustav-Channel, Larsen Inlet, Larsen-A/B and Wordie ice shelf regions. We analyse time series of synthetic aperture radar (SAR) data in regard to surface velocities using SAR intensity offset tracking. Optical satellite data as well as data from various altimetry missions (ICESat, CryosSat-2, NASA Operation IceBridge) as well as from the German bi-static SAR mission TanDEM-X are analysed in regard to surface elevation changes. We compile those data sets to time series in order to study the adaptation of the glacier systems to ice shelf break-up and glacier retreat. Using ice thickness estimates from Huss & Faronitti (2013) as well as surface mass balance output from the recent refined RACMO-2 runs for the Antarctic Peninsula, we estimate the mass loss by the flux gate approach (also referred to as input-output method). Our analysis reveal a quite distinctive response patterns of the glacier systems depending on the prevailing conditions. We estimate a mass budget of −40.7±3.9 Gt (1995-2014) for the Dinsmoor-Bombardier-Edgeworth glacier system (DBE, formerly draining into Larsen-A), -50.9±8.3 Gt (1993-2014) for Sjögren Inlet (formerly draining into Prince Gustave-Channel Ice Shelf). For DBE, the contribution to sea level rise was estimated to be 18.8±1.8 Gt, corresponding to a 0.052±0.005 mm sea level equivalent, for the period 1995–2014 and for Sjögren Inlet 0.0798±0,0145 mm SLE in 1993-2014. For the entire northern Antarctic Peninsula our computations reveal a mass loss 0f -0.64 Gt yr-1 (1992-96) while for recent years (2010-2014) a positive balance of 2.51 Gt yr-1 was retrieved. On the southern Antarctic Peninsula at tributaries of the former Wordie Ice Shelf our

observations reveal a partial ungrounding with considerable speed-up and mass loss of tributary glaciers. This shows that the systems have yet not fully adapted to the ice shelf loss and upwelling of warmer Antarctic bottom water might have triggered the further grounding line retreat. In our contribution we show that modern satellite observations can constrain the adaptation in surface velocity and surface elevation reasonably well. However, our analysis also shows that still largest uncertainties result from unknown ice thickness – in particular before ice shelf collapse – as well as surface mass balance.

Poster #29

Determination of spatio-temporal velocity fields at Grey Glacier using terrestrial and satellite imagery

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Abstract

Since several years most glaciers all over the world are showing increasing retreat, thinning and acceleration. To understand and model the phenomena as well as to predict the future development of ice fields and glaciers, glaciologists need different data that describe the glaciers condition. Therein, an important issue is the determination of velocity fields. These can be derived using remote sensing as well as terrestrial methods. We introduce both a terrestrial image sequence as well as a satellite image-based technique for the analysis of the motion behavior of Grey Glacier in the Southern Patagonian Icefield.

Using the example of Grey Glacier we describe the principle of velocity field determination from monoscopic terrestrial image sequences. The images were recorded in March 2014 with a time interval of 20 min over several days using a 12 Megapixel digital camera. In these image sequences, a large number of glacier surface points were tracked by subpixel accuracy feature tracking techniques. Evaluating a photogrammetric network, that has been supported by GPS and laser distance measurements, the obtained trajectories could be scaled and georeferenced. The technique allows for tracking a dense raster of glacier surface points at measurement accuracy in the order of several centimeters. We determined the maximal flow velocity of Grey Glacier with 2.8 md^{-1}.

In order to validate the obtained measurement values the results were compared to velocity fields derived from optical remote sensing data, acquired by Landsat´s 8 OLI sensor system. For this purpose two panchromatic scenes from 23th of January to 24th of February 2015 have been chosen for the application of cross-correlation feature tracking by ENVI´s add-on COSI-Corr (Co-registration of Optically Sensed Images and Correlation), which uses an iterative phase correlation algorithm in frequency space with a joined subpixel shift detection. The estimated displacement vectors were filtered to remove potential mismatches, outliers and displacement anomalies in relation to the main flow direction. The period of a month between both scenes allows a day-related

velocity measurement. Compared to our results from terrestrial images we observed a maximal flow velocity of 3 md^{-1} too.

The comparison of the results in the overlapping area shows that the obtained velocities from the terrestrial measurements are in good agreement with the tracking results of the Satellite imagery.

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