20igsnb3618

Greenland ice sheet mass balance 1992-2020 from radar altimetry

Sebastian B. Simonsen, Valentina Barletta, Louise Sandberg Sørensen, William Colgan

Corresponding author: Sebastian B. Simonsen

Corresponding author e-mail: ssim@space.dtu.dk

Student?No

Satellite radar altimetry provides elevation change estimates of the Greenland Ice Sheet since 1991, which covers the entire ice sheet. However, the record is difficult to translate into mass balance due to climate-induced variations in surface penetration which is seen as elevation change in the record. On the other hand, satellite Lidar altimeters (ICESat and ICESat-2) provides high-spatial resolved mass balance estimate from precise observations of surface elevation change, but is only available from 2003–09 and again from 2018. Here, we apply machine learning to build an empirical conversion from radar-derived volume change to mass balance, based on our knowledge gained from the limited periods of satellite Lidar altimetry. This mass balance record from radar altimetry shows that the contribution from the Greenland Ice Sheet to global sea-level rise has been 12.1±2.3 mm since 1992, with more than 80% of the contribution originating after 2003. The results from the empirical method presented here circumvent the need for radar-propagation modeling and clears the path for operational mass balance estimates from satellite radar altimetry.

20igsnb3619

Water content of firn at Lomonosovfonna, Svalbard, derived from subsurface temperature measurements

Sergey Marchenko, Ward van Pelt, Rickard Pettersson, Veijo Pohjola, Carleen Reijmer

Corresponding author: Sergey Marchenko

Corresponding author e-mail: sergey.marchenko@geo.uu.se

Student?No

The potential of capillary forces to retain water in pores is an important property of snow and firn at glaciers. Melt water suspended in pores does not contribute to runoff and may refreeze during winter, by this affecting the climatic mass balance and the subsurface density and temperature. However, measurement of the snow/firn water content is challenging and few values have been reported in literature. Here we use subsurface temperature and density measured at the accumulation zone of Lomonosovfonna (1200 m a.s.l., Svalbard, to derive water content of the firn profiles after the melt seasons in 2014 and 2015. For that we compare the measured and simulated rates of freezing front propagation. The calculated volumetric water content of firn is ca 1.0–2.5 vol. % above the depth of 3 m and less than 0.5 vol. % below. Results derived using different thermistor strings suggest a prominent lateral variability in firn water content. Reported values are considerably lower than commonly used in snow/firn models. This is interpreted as a result of preferential water flow in firn leaving extensive dry pockets between wetted firn volumes and calling for implementation of preferential flow description in snow/firn models, constrained by empirical water content estimates.

20igsnb3620

Holocene minimum extent of Jakobshavn Isbræ shows an approaching tipping point

Karita Kajanto, Helene Seroussi, Basile de Fleurian, Kerim Nisancioglu

Corresponding author: Karita Kajanto

Corresponding author e-mail: karita.kajanto@uib.no

Student?Yes

The evolution of marine terminating glaciers under the warmer than present Holocene Climate Optimum climate can give important insights into the dynamics of ice streams as the climate evolves. The early Holocene evolution of Jakobshavn Isbræ, from the Last Glacial Maximum extent up to 8.2 ka BP is well constrained by geomorphological studies in the area. However, the Holocene minimum extent of the glacier is unknown. Here, we use a high-resolution regional ice sheet model to study the retreat and readvance of Jakobshavn Isbræ from the Mid-Holocene to the Little Ice Age. This model of Jakobshavn Isbræ accurately tracks the terrestrial ice margin and agrees with available estimates of marine grounding line evolution. We find that the Holocene minimum extent of both the terrestrial ice margin and the grounding line, reached at 6–5 ka BP, is close to the present day extent of the glacier. We also find that the glacier is currently located close to a tipping point, from beyond which readvance would require a longer and more significant cooling than the Little Ice Age. We assess the importance of the ocean forcing in explaining the Holocene evolution of Jakobshavn, and find that cooling within the fjord during the Mid-Holocene is critical for the glacier to readvance. This finding emphasizes the role of ocean forcing when trying to understand the millenial scale evolution of marine terminating glaciers.

20igsnb3621

Cold ice in a warm bath: what's driving an Arctic glacier's retreat from a proglacial lake?

Adrian Dye, Joseph Mallalieu, Fran Falcini

Corresponding author: Adrian Dye

Corresponding author e-mail: adrian.dye@york.ac.uk

Student?No

Studies in Patagonia, Nepal and New Zealand have shown that where glaciers terminate in proglacial lakes glacier mass loss is accelerated through thermal and mechanical processes, particularly through the formation of thermal notches in the ice front. Despite this there are limited studies into the thermal regime of proglacial lakes and observations of temperature directly at the ice water contact point. The abundance and temperature of these proglacial lakes in Arctic glacier systems has received relatively little attention, which needs to be addressed given recent extreme heat events and the Arctic Amplification of increased air temperatures. We present proglacial lake temperatures and a calving mechanism record, including analysis of iceberg movement at the ice front through the 2017 and 2019 melt season at an Arctic lacustrine glacier.

We recorded proglacial lake thermal regime at an Arctic glacier, using in situ and spatial surveys, including use of thermal infrared imagery. This is an important advance as previous melt models for lacustrine terminating glaciers have been compromised by a lack of data from the hazardous water to ice contact point and assume a uniform temperature (e.g. 1oC). During the 2017 melt season, winds were blowing away from the glacier and water temperatures of ~3oC were recorded at the ice front. Whereas during the 2019 melt season winds were predominantly blowing towards the glacier, resulting in water temperatures of up to ~5oC directly at the ice front (recorded over 12 days). Time lapse imagery was used to analyse terminus geometry change in both field seasons at the front of an actively calving Arctic glacier (67.954878°N, 18.561535°E), which rapidly lost 10,523m2 of ice (0.67% of area in RGI, 2008) between 2014 to 2018. We present a calving mechanism record from 2017 and 2019, with the majority of events being driven by melt undercutting. The analysis of iceberg movement reveals complex circulation patterns at the ice front, which play a strong role in subaqueous mass loss and changing geometry of the ice front during a period of relatively rapid retreat.

We work towards developing a time series of iceberg calving volume from SfM analysis of time lapse imagery and sonar analysis to determine subaqueous geometry and melt rates (Mallalieu et al., 2017). Advances in this research are particularly pertinent given reported warming trends of 0.08oCy-1 in lakes across Northern Europe (Hook and Schneider, 2010).

20igsnb3623

Spring Arctic sea ice variability and its impact on Indian summer monsoon

Suchithra Sundaram

Corresponding author: Suchithra Sundaram

Corresponding author e-mail: suchithrasundaram@gmail.com

Student?No

The polar regions over the earth represent the most sensitive regions on the globe as far as global warming is concerned. The immediate impact of unprecedented warming gets reflected on the polar regions in the form of glacial and sea ice melt. The Arctic sea ice that is declining at an alarming rate has a tremendous impact on local, regional, and global climate. Sea level changes, an increase of extreme weather events over Europe are a few of them. Concurrently the Indian summer monsoon that occurs during June-September of each year shows great regularity in its occurrence. But the vagaries in the Indian summer monsoon (ISM) rainfall lead to large interannual variabilities in the monsoon rainfall leading to the flood and drought years. Various ocean-atmospheric processes like the El Niño–Southern Oscillation, Indian Ocean dipole, Eurasian snow cover appear to contribute to this rainfall variability through the process known as teleconnections. Climate modeling studies predict that the frequency of occurrence of extreme weather events associated with the Indian monsoon may increase in the future due to global warming. The current study examines whether there exists any link between the sea ice variability of the Arctic during spring and the Indian summer monsoon. The study employed the analysis of fifty years (1951–2000) of NCEP/NCAR reanalysis, Hadley Center Sea Surface Temperature and Sea ice, and the India Meteorological Department precipitation datasets. The preliminary results indicate that the spring Arctic sea ice over the eastern Arctic has a role in linking Arctic climate variability with the same year's Indian summer monsoon, in addition to the North Atlantic Sea Surface Temperature. Further analysis with satellite/reanalysis/observational datasets and climate model simulations will be doing to get a better understanding of the physical processes underlying this relationship.

20igsnb3624

Seasonal dynamics of snow ablation on selected glaciers in central Spitsbergen derived from Sentinel-2 satellite images

Jan Kavan, Vincent Haagmans

Corresponding author: Jan Kavan

Corresponding author e-mail: jan.kavan.cb@gmail.com

Student?No

The dynamics of seasonal snow ablation on 6 glaciers in central Spitsbergen (Dicksonland) were assessed by examining a set of Sentinel-2 satellite images covering the summer ablation season for the period 2016–19. All glaciers lost 80% or more of their surface snow cover during the studied ablation seasons. This bolsters the recently observed trend of local glacier thinning, even in the high-altitude zones. Snow ablation dynamics are highly dependent on the glaciers altitudes, their position relative to the prevailing wind direction and the exposure to insolation. The accumulation areas of the studied glaciers were delimited based on the overlap of the minimal extent of snow-covered areas in the 4 consecutive studied summer seasons. The high temporal and spatial resolution of available images enabled a detailed description of the seasonal snow ablation dynamics. Moreover, an estimate of the average number of days with below threshold glacier snow cover was made. This study contributes to our understanding of recent processes and might further support the modelling of glacier melt and subsequent runoff.

20igsnb3626

High resolution ice shelf freeboard, thickness, draught, and basal melt in Dronning Maud Land from Reference Elevation Model of Antarctica (REMA) strips

Ashley Morris, Geir Moholdt, Laurence Gray

Corresponding author: Ashley Morris

Corresponding author e-mail: richard.ashley.morris@npolar.no

Student?No

The stability of the ice shelves that fringe Antarctica is a critical control on the mass balance of the ice sheet, and hence changes in global sea level. Ice shelves are thought to be sensitive not only to the magnitude of basal melt, but also its spatial pattern, with melt often concentrated near the grounding line, calving front, and within channels incised into the ice shelf base. The 'Ocean-ice shelf interaction and channelized melting in Dronning Maud Land' project combines oceanographic and glaciological field data, satellite remote sensing, and modelling to improve our understanding of ice-ocean interaction beneath Fimbulisen and neighbouring ice shelves in the Norwegian sector of east Antarctica. Here, we present a new high-resolution digital elevation model (DEM) to be used as a boundary condition for modelling, and map of basal melt pattern for these ice shelves.

Reference Elevation Model of Antarctica (REMA) strips are freely available 8m-resolution stereoscopic DEMs derived from satellite imagery, covering the period 2009-2017. Mosaicking the strips to produce large-scale DEMs is complicated by the advection of surface topography with ice flow. We use velocity fields to warp strips forward or backwards in time as necessary, such that topography is continuous across strip boundaries, before validating elevations against CryoSat-2 radar altimetry. The final mosaic was then converted from ellipsoidal height to freeboard, thickness and draught assuming hydrostatic equilibrium. Additionally, we map basal melt rates in a Lagrangian reference frame using a similar warping technique, refined with image cross-correlation.

20igsnb3627

Glacier retreat in northern Norway since the Little Ice Age maximum

Joshua Leigh, Chris Stokes, David Evans, Rachel Carr, Liss Andreassen

Corresponding author: Joshua Leigh

Corresponding author e-mail: joshua.r.leigh@durham.ac.uk

Student?Yes

Small mountain glaciers are an important part of the cryosphere which tend to respond rapidly to climate warming. Recent observations worldwide document increasing rates of mountain glacier recession. Here, we map recent (post-1980s) changes in ice extent across a 9600 km^2 region of Troms and Finnmark county from remotely sensed data and report that between 1989 and 2018, the glacierized area (n = 219 glaciers in 1989) shrank from ~102 to ~66 km^2 (35%). Very small glaciers (<0.5 km^2) show the highest relative rates of shrinkage and 90% of mapped glaciers within the study area are now less than 0.5 km^2. Using a set of objective criteria to identify very small glaciers, we were able to find and map 78 additional glaciers (on the 1989 imagery) which were not included in the most recent (2012) iteration of the Inventory of Norwegian Glaciers. Finally, we visited a small subset of mountain glaciers situated within the Rotsund Valley, Nordreisa municipality, to undertake lichenometric dating and detailed surficial geological mapping to establish the timing and extent of the Little Ice Age (LIA) maximum; mapping and dating revealed that LIA maximum occurred as early as 1814 (±41 years). Extrapolation of our site-specific dating enabled LIA reconstructions for a small subset of glaciers (n = 15) within the same mountain belt. We show that for the 15 glaciers with LIA reconstructions their area shrank from 10 km^2 at LIA maximum to 6.2 km^2 in 1989 and to 3.1 km2 in 2018; this equates to a 69% area reduction over the past ~200 years. Finally, we note that all glaciers that shrank by >50% since their LIA maximum are fronted by proglacial lakes.

20igsnb3628

Modelling a perennial firn aquifer on the Lomonsovfonna ice field

Tim van den Akker, Ward van Pelt, Carleen Reijmer, Veijo Pohjola, Rickard Petterson

Corresponding author: Tim van den Akker

Corresponding author e-mail: t.vandenakker@students.uu.nl

Student?Yes

Recently, large bodies of water stored in pore spaces of firn, referred to as firn aquifers, have been discovered on the GrIS and Spitsbergen. These firn aquifers ('perennial firn aquifers' (PFAs) if they persist for multiple years) can exchange energy with the surrounding firn, slow down sea level rise and alter the dynamics of glaciers. Not much is known on the dynamics of PFA's. We approached a PFA-system as a groundwater system and modelled the PFA discovered on the Lomonosovfonna ice field (Svalbard) using MODFLOW 6, a groundwater flow solver algorithm. The model is calibrated against ground-penetrating radar measurements obtained during field campaigns in 2015-2019. The hydraulic conductivity distribution was used as a tuning parameter. The resulting 'best fit' hydraulic conductivity showed to be a third order polynomial as function of the density.

The results show that the PFA on the Lomonsonovfonna likely was present in 1957, and that it grew in height with 10 meters from 1957–2019. The model was then run for RCP 4.5 and 8.5, and the water table height increased from 2019–2060 with 12.5 and 20 meters for the respective scenarios, with the largest increases happening at places with a high surface slope. The flow vectors generally follow the shape of the surface profile, and the model predicts the water table to reach the snow surface around 2045 for both scenarios. In 2060, more than half the modelled grid has a water table at the snow surface for RCP 8.5. The water table shows almost immediate responses to meltwater input during the melt season, and the water table linearly decreases during winter time.

This model can be used on different sites, such as the GrIS, if there is data available on the snow conditions. Firn-aquifer interactions, such as refreezing, are not part of this model, and could be a good starting point for further research.

20igsnb3629

SIOS's practical activities to fill gaps in scientific observations and bringing the scientific community together during the global pandemic of COVID-2019

Shridhar Jawak, Veijo Pohjola, Inger Jennings, Christiane Hübner, Dariusz Ignatiuk, Øystein Godøy, Heikki Lihavainen, Bo Andersen, Kim Holmén

Corresponding author: Shridhar Jawak

Corresponding author e-mail: shridhar.jawak@sios-svalbard.org

Student?No

Svalbard Integrated Arctic Earth Observing System (SIOS) is an international collaboration of 24 research institutions from 9 countries studying the environment and climate in and around Svalbard to address broad earth system science questions. This presentation will mainly focus on the activities of SIOS Knowledge Centre (SIOS-KC) and Remote Sensing Working Group (RSWG) in response to the challenges posed by global pandemic COVID-19. The pandemic has affected the Svalbard research in several ways because of nationwide lockdown in many countries, strict travel restrictions in Svalbard, and quarantine regulations. Additionally, most of the physical meetings and conferences were cancelled since the beginning of the pandemic in the first week of March 2020. Because of this, many countries started closing borders disabling travels to Svalbard. This resulted in cancellations of numerous planned field campaigns to Svalbard. In response to this new situation, SIOS developed a new set of activities suitable to counteract these challenges. This presentation provides a summary of SIOS's operational activities designed in response to COVID-19 to support the Svalbard scientific community. These activities include (1) patching up scientific data with remote sensing observations, (2) logistics services for essential field activities in the pandemic times, (3) a monthly webinar series and panel discussion to engage the scientific community, (4) the online conference on Earth observation and remote sensing, (5) launching a special issue in an international journal, (6) the online version of terrestrial remote sensing training course, and (7) the announcement of opportunity in airborne remote sensing using aerial imagery and hyperspectral data using drones and aircraft. We hope that our practical services and activities implemented in these times will motivate other similar monitoring programs and observing systems to respond to future disruptions to research activity.

20igsnb3630

Ocean sound field components in Kongsfjorden, Svalbard and its distribution

Sanjana M C

Corresponding author: Sanjana M C

Corresponding author e-mail: sanjana@niot.res.in

Student?No

An Automated Noise Measurement System (ANMS) was deployed at the central part of Kongsfjorden fjord, during 2018-2019 for acquiring long term measurements towards Passive Acoustic Montoring (PAM). Previous studies of noise field at the site suggested the presence of surface sound channels, which are pronounced during fall and winter seasons at central Kongsfjorden. The ANMS consisted of hydrophones positioned within the surface sound channel and outside the channel, and acquired data is stored in data acquisition modules enclosed in subsea casing. Monthly estimates from July 2018 to February 2019 have been examined for noise field due to local and distant sources. The hydrophone within the surface duct captures noise that travels long distance, and thus gives a higher than normal noise level at the location. The spatial correlation in noise between the hydrophones separated vertically, is checked for direction of arrival within 500 Hz. Signal correlation studies in the band within 500 Hz is important for Ice dynamics, anthropogenic noise as well as environmental noise.

The influence of glacial melt water from the adjoining Kronebreen and Kongsvegan glaciers on hydrology and sound speed profile, and resulting ducted propagation along the surface is discussed. The decline in sea ice extent, thickness and overall concentration will shift the ecosystem to a warmer, more ice free state, favouring acoustic propagation of low frequency signals and can lead to remarkably high ambient noise levels.

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20igsnb3631

Rapid erosion of a subglacial landform under the Rutford Ice Stream, West Antarctica

Rebecca Schlegel, Tavi Murray, Andrew Smith, Edward King, Alex Brisbourne

Corresponding author: Rebecca Schlegel

Corresponding author e-mail: earrsch@leeds.ac.uk

Student?Yes

Subglacial lineations, such as mega-scale glacial lineations and drumlins, are known to be indicative of fast ice flow. A better understanding of the mechanisms controlling fast ice flow, and therefore basal topography and properties (e.g. water content, roughness), are important inputs for models to predict future dynamics and losses of the West Antarctica Ice Sheet.

The Rutford Ice Stream (RIS) (more than 2km thick, of which 1.4km is below sea level) is a fast-flowing glacier in West Antarctica: the ice surface speed at the grounding line is >1 m/day, and has been stable over the past 30 years. The ice-bed interface is at the pressure-melting point. Legacy radio-echo sounding (RES) and seismic profiles revealed highly elongated lineations, up to ~14 km long, up to 150 m high, and 50-500 m wide, aligned in the ice-flow direction. Some areas of the bed of the Rutford Ice Stream have been observed to be very mobile, with erosion and subsequent deposition of soft sediment, in the form of landforms.

Within this study we present evidence of erosion of material in various areas of the RIS bed over a 9-year period, at an averaged erosion rate of 1m/a in those locations. Erosions were detected by comparison of RES data acquired in 2007/08 and the repetition of the same survey lines in 2016/17. The most fascinating erosion appears continuous over several kilometres downstream and shows the (partial) erosion of a landform. We believe this to be the first observation of an active erosion of a landform. No clear evidence for erosion by a floodwater event or other abrupt mechanisms can be found, as no variations in ice flow or surface elevations have been observed over the 9-year period. The observation of the removal of an individual landform on a bed that is laced with landforms, opens the question if there is a link to the landform formation processes.

20igsnb3632

Long-term future projections for the Greenland ice sheet with the model SICOPOLIS

Ralf Greve, Christopher Chambers, Reinhard Calov

Corresponding author: Ralf Greve

Corresponding author e-mail: greve@lowtem.hokudai.ac.jp

Student?No

The Coupled Model Intercomparison Project Phase 6 (CMIP6) is a major international climate modelling initiative. As part of it, the Ice Sheet Model Intercomparison Project for CMIP6 (ISMIP6) was devised to assess the likely sea-level-rise contribution from the Greenland and Antarctic ice sheets until the year 2100. This was achieved by defining a set of future climate scenarios by evaluating results of CMIP5 and CMIP6 global climate models (GCMs, including MIROC) over and surrounding the Greenland and Antarctic ice sheets. These scenarios were used as forcings for a variety of ice-sheet models operated by different working groups worldwide.

Here, we use the model SICOPOLIS to carry out extended versions of the ISMIP6 future climate experiments for the Greenland ice sheet until the year 3000. We employ two different ice-dynamics schemes, SIA (shallow-ice approximation) and HYB (hybrid shallow-ice-shelfy-stream dynamics). For the atmospheric forcing (anomalies of surface mass balance and temperature) beyond 2100, we sample randomly the ten-year interval 2091-2100, while the oceanic forcing (prescribed retreat due to ocean thermal forcing) beyond 2100 is kept fixed at 2100 conditions. Twelve experiments are for the pessimistic, 'business as usual' pathway RCP8.5 (CMIP5) / SSP5-8.5 (CMIP6), and two are for the optimistic RCP2.6 (CMIP5) / SSP1-2.6 (CMIP6) pathway that represents substantial emissions reductions. For the control run with a constant, 1960-1989 average climate, the ice sheet is stable until the year 3000. For RCP8.5/SSP5-8.5, it suffers a severe mass loss, which amounts to ~1.7 m SLE (sea-level equivalent), or ~25% of its entire mass, for the twelve-experiment mean, and ~3.5 m SLE (~50% of the entire mass) for the most sensitive experiment. For RCP2.6/SSP1-2.6, the mass loss is limited to a two-experiment mean of ~0.26 m SLE. Climate-change mitigation during the next decades will therefore be an efficient means for limiting the contribution of the Greenland ice sheet to sea-level rise in the long term.

20igsnb3633

Accelerating projected mass loss of Svalbard glaciers from a multi-model ensemble

Ward van Pelt, Thomas V Schuler, Rickard Pettersson, Veijo Pohjola

Corresponding author: Ward van Pelt

Corresponding author e-mail: wjjvanpelt@gmail.com

Student?No

Continued above-average warming and wettening will have a strong impact on the state of glaciers and seasonal snow in the High Arctic. Following up on a recent historical simulation (1957–2018) for Svalbard, we now present future projections of glacier climatic mass balance, snow conditions on glaciers and land, and runoff, under Representative Concentration Pathways (RCP) 4.5 and 8.5 emission scenarios for 2019–60. The model output reveals that the average climatic mass balance for Svalbard glaciers, which was previously found to be weakly positive during 1957-2018, becomes negative at an accelerating rate during 2019-2060 for both scenarios. Most pronounced mass loss occurs in southern Svalbard, where the equilibrium line altitude rises well beyond the peak in hypsometry, causing projected first occurrences of zero accumulation-area ratio in the 2030s. In parallel to firn line retreat, we find that total pore volume in snow and firn drops by as much as 70–80% in 2060 compared to 2018. Total refreezing remains largely unchanged despite a marked change in the seasonal pattern towards increased refreezing in winter. Furthermore, we find a pronounced reduction of the snow season length with comparable contributions from earlier snow melt in spring and later snow onset in autumn. Combined runoff from glaciers and land more than doubles from 1957-2018 to 2019-2060 for both scenarios. Finally, a sensitivity experiment with dynamic glacier geometry for large land-terminating glaciers hints towards a limited impact of our assumption of a constant glacier geometry on simulated runoff and CMB.

20igsnb3634

Improved ice velocity measurements with Sentinel-1 TOPS interferometry

Jonas Kvist Andersen, Anders Kusk, John Merryman Boncori

Corresponding author: Jonas Kvist Andersen

Corresponding author e-mail: jkvand@space.dtu.dk

Student?No

The Copernicus Sentinel-1 Synthetic Aperture Radar (SAR) system, featuring a 6-day repeat pass period and the Interferometric Wide (IW) swath acquisition, is currently the most commonly applied system for acquiring ice sheet and outlet glacier motion measurements. Such measurements are routinely generated using offset tracking techniques, which have the advantage of being applicable even on fast-flowing outlet glaciers, although the velocity measurements are generally of poor accuracy and the achievable spatial resolution is, at best, several hundred meters. Conversely, differential SAR interferometry (DInSAR) generally achieves high accuracy and high spatial resolution, while not being applicable on very fast-flowing outlet glaciers. An obvious synergy thus lies in applying both offset tracking and interferometric techniques to the Sentinel-1 data archive, yielding velocity measurements of high accuracy and resolution in the interior parts of the Greenland ice sheet as well as an extensive coverage of outlet glaciers provided by offset tracking.

While such a combination of SAR techniques has been exploited in the generation of Greenland/Antarctic ice velocity maps, Sentinel-1 interferometry is not currently applied for the generation of such products. This is mainly due to a feature of Sentinel-1's main acquisition mode, namely TOPS, in which the azimuth antenna steering introduces a coupling between interferometric phase and azimuth registration. This in turn complicates interferometric processing and requires a highly accurate azimuth coregistration procedure. If not accounted for, the azimuth motion component of the ice sheet will cause interferometric phase gradients across each burst, resulting in phase discontinuities at burst boundaries.

We present a Sentinel-1 interferometric processing chain, which reduces the azimuth coupling to the line-of-sight phase signal through a spatially adaptive coregistration refinement incorporating azimuth velocity measurements. The DInSAR processing chain is demonstrated for a large drainage basin in Northeast Greenland, encompassing the Northeast Greenland Ice Stream (NEGIS), and integrated with state-of-the-art offset tracking measurements. In the ice sheet interior the combined DInSAR and offset tracking ice velocity product provides a spatial resolution of 50 m x 50 m and 1-sigma accuracies of 0.18 m/y and 0.44 m/y in the x and y components respectively, compared to GPS.

20igsnb3635

The bedrock and tephra layer topography within the glacier filled Katla caldera, Iceland, deduced from dense RES-survey

Eyjólfur Magnússon, Finnur Pálsson, Alexander H. Jarosch, Tayo van Boeckel, Hrafnhildur Hannesdóttir, Joaquín M.C. Belart

Corresponding author: Eyjólfur Magnússon

Corresponding author e-mail: eyjolfm@raunvis.hi.is

Student?No

We present results from recent low frequency radio echo sounding (RES) campaign over the ice-covered caldera of Katla central volcano in Mýrdalsjökull ice cap S-Iceland. The current RES survey partly repeats but more so enhances the RES network of 1991 (Björnsson et al. 2000) with denser sounding lines and improved instruments. The RES data obtained in 2012-2019 includes ~750 km of 2D migrated RES profiles covering an area of 112 km^2. Around 13 km^2 subsections of this area were surveyed with RES profiles 20 m apart allowing 3D migration of the RES data. Our study confirms findings from previously published bedrock, including main topographic features, ice volume stored within caldera (45±2 km^3, in autumn 2019) and maximum ice thickness (740±40 m). However, the significantly expanded level of detail and features observed in the new bedrock DEM, reveals further evidences of complex and eventful formation history. The new RES data allows for a unique comparison of bedrock maps obtained from RES data with 2D and 3D migration, demonstrating the limitation of 2D migrated RES data in areas of high topographic variability. Reflections from the 1918 Katla eruption tephra layer within the ice were detected in a much wider area within the caldera than in 1991 and we also observe a second internal layer at 420-580 m depth within the northern part of the caldera, identified here as the tephra from the 1755 Katla eruption. The 1918 tephra layer is typically observed at 200-300 m below the glacier surface. However, the layer depth varies from ~100 m depth at the western rim of the caldera down to 450 m depth due to geo¬thermal activity beneath ice cauldrons. At the most prominent geothermal areas all ice beneath the 1918 tephra has all been melted from below leaving the tephra at the bed. Furthermore, the tephra layer maps, deduced in this study, reveal footprints of some previously unidentified geothermal areas.

20igsnb3636

Summer DEM for the marginal areas of the Greenland ice sheet and elevation along the PROMICE flux gates

Mai Winstrup, Louise Sandberg Sørensen, Kenneth Mankoff

Corresponding author: Mai Winstrup

Corresponding author e-mail: maiwin@space.dtu.dk

Student?No

Over recent decades, the Greenland ice sheet has shown a clear trend of mass loss at an increasing rate. One way of quantifying the annual ice-sheet mass discharge is by coincident measurements of ice velocity and ice thickness along fluxgates at glacier outlets around the ice sheet margin. As part of the Programme for Monitoring of the Greenland Ice Sheet (PROMICE), we here obtain annual estimates for the ice thickness along pre-designated PROMICE fluxgates near the grounding line of individual outlet glaciers using satellite altimetry data from ICESat-2 and CryoSat-2. High-resolution elevation data along the flux-gates are derived as part of the construction of an annual 1x1km Digital Elevation Model (DEM) for the marginal areas of the Greenland ice sheet during summer. Starting with elevation data from summer 2019, these data will improve the annual assessments of the dynamic mass loss of the Greenland ice sheet.

20igsnb3637

Subglacial permafrost dynamics and erosion inside subglacial channels driven by surface events in Svalbard

Andreas Alexander, Jaroslav Obu, Thomas V. Schuler, Andreas Kääb, Hanne H. Christiansen

Corresponding author: Andreas Alexander

Corresponding author e-mail: andreas.alexander@geo.uio.no

Student?Yes

Cold glacier beds, i.e. where the ice is frozen to its base, are widespread in polar regions. Common theories state that stable permafrost should exist under glacier beds on shorter time scales, varying from years to decades. Presently, only a few direct measurements of both subglacial permafrost and the processes influencing its thermal regime exist. Here, we present subglacial permafrost and active layer measurements obtained from within the basal drainage systems of two cold-based glaciers on Svalbard during the summer melt season. Temperature observations were obtained from subglacial sediment that was accessed through the drainage systems of the two glaciers in the winters before. The temperature records cover the periods from spring to autumn in 2016 and 2019, at the glaciers Larsbreen and Tellbreen in central Svalbard, respectively. The ground temperature below Larsbreen indicates colder ground conditions, whereas the temperatures of the Tellbreen drainage system show considerably warmer conditions, close to the freezing point. We suggest the latter is due to the presence of liquid water all year round inside the Tellbreen drainage system. Both drainage systems investigated show an increase in subglacial sediment temperatures after the disappearance of snow bridges and the subsequent connection to surface meltwater supply at the start of the summer melt season. Temperature records show influence of sudden summer water supply events, when heavy melt and rain left their signatures on the thermal regime and the erosion of the glacier bed. Observed vertical erosion can reach up to 0.9 m per day at the base of basal drainage channels during summer. We also show that the thermal regime under the subglacial drainage systems is not stable during summer, but experiences several freeze-thaw cycles driven by weather events. Our results show the direct importance of heavy melt events and rain on the thermal regime of subglacial permafrost and the erosion of the glacier bed in the vicinity of subglacial drainage channels. Increased precipitation and surface melt, as expected for future climate, will therefore likely lead to increased degradation of subglacial permafrost, as well as higher subglacial erosion of available sediment around the preferential hydrological paths. This in turn might have significant impacts on proglacial and fjord ecosystems due to increased sediment and nutrient input.

20igsnb3638

Topology and pressure distribution reconstruction of an englacial channel

Andreas Alexander, Laura Piho, Maarja Kruusmaa

Corresponding author: Andreas Alexander

Corresponding author e-mail: andreas.alexander@geo.uio.no

Student?Yes

Glacial hydrology describes the way how water can move over, through and under glaciers. Generally meltwater flows every summer over the surface of glaciers and ice sheets, creating pathways down to below the surface, eventually reaching the glacier bed and thereby influencing ice motion. Glacier and ice sheet models, trying to predict their future sea-level rise contribution need to therefore be able to properly describe glacial hydrological processes. However, the current process understanding is still limited due to the lack of measurement technology for subsurface in-situ flow observations. Here we present a method that allows to reconstruct planar subsurface water flow paths and spatially reference water pressures therein. The method uses inertial measurements from sensing drifters and reconstructs the flow path from given start and end coordinates. Validation cases show an average error of 3.90 m compared to GNSS reference. We use this model to reconstruct the flow path and the spatial water pressure distribution of an englacial channel on Austre Brøggerbreen (Svalbard). The average error of the path is thereby 12.1 m and the average pressure error 3.4 mbar (0.3\%). Our method will allow to study englacial and subglacial flow paths and the pressure distributions therein, thereby allowing for model validation and activation. Further on, our method also allows to reconstruct other subsurface flow paths, when a global spatial reference (e.g. GNSS) is not available.

20igsnb3639

Characteristics of ice rises in Dronning Maud Land, Antarctica

Vikram Goel, Kenichi Matsuoka, Carlos Martín, Joel Brown, Cesar Deschamps Berger, Ian Lee, Jørgen Dall, René Forsberg

Corresponding author: Vikram Goel

Corresponding author e-mail: vikram.goel@outlook.com

Student?No

Ice rises are locally grounded and elevated features surrounded by floating ice shelves. They help regulate the outflow of ice from the Antarctic Ice Sheet, besides, holding past climate information within their ice stratigraphy. The Dronning Maud Land (DML) coast in East Antarctica is abundant with ice rises with highly variable settings. Our analysis using satellite imagery, surface mass balance and ice thickness data shows that large parts of coastal DML have been changing over the past several millennia. In addition, we examined three ice rises located within Fimbul Ice Shelf in DML, determining their glaciological settings and past evolution, using ground-based geophysical measurements and numerical ice-flow modelling. Here we present a synthesis of our results and discuss the emerging picture of the dynamics of this region.

20igsnb3640

How much water is in that snow? Solving the very old problem of SWE

Hamish Pritchard, Daniel Farinotti, Steve Colwell

Corresponding author: Hamish Pritchard

Corresponding author e-mail: hprit@bas.ac.uk

Student?No

The Snow Water Equivalent (SWE) of snowfall is difficult to measure. This is a problem because the water stored in snow is important. Every glacier and ice sheet in the world is made of it and each year it covers a third of the Earth's land, dominating the water supply for one sixth of the world's population and a quarter of global GDP. Climate models need to be tuned to SWE measurements to predict water supplies in river basins and mass loss from the cryosphere to the oceans. However, while numerous techniques have been developed over the last 800 years, SWE measurements are still too sparse, too poorly distributed, too infrequent, too small and too biased to represent the variability of SWE in mountain landscapes.

We have developed a novel measurement technique that provides direct observations of changing SWE in Arctic and Alpine settings on far larger spatial scales (millions of square metres), comparable to the grid cells of climate models. It is autonomous, high-frequency, high-resolution, low-cost and low-bias. Tests of this new technique show that it is highly sensitive to falling snow, and they highlight the sometimes large biases present in conventional instruments and operational weather forecast models.

20igsnb3641

A national glacier inventory and variations in glacier extent inIceland from the Little Ice Age maximum to 2019

Hrafnhildur Hannesdóttir, Oddur Sigurðsson, Ragnar Heiðar Þrastarson, Snævarr Guðmundsson, Joaquín M.C. Belart, Finnur Pálsson, Eyjólfur Magnússon, Skúli Víkingsson, Tómas Jóhannesson

Corresponding author: Hrafnhildur Hannesdóttir

Corresponding author e-mail: hrafnha@hi.is

Student?No

A national glacier outline inventory for several different times since the end of the Little Ice Age(LIA) in Iceland has been created with input from several research groups and institutions, and submitted to the GLIMS (Global Land Ice Measurements from Space, nsidc.org/glims) database, where it is openly available.The glacier outlines have been revised and updated for consistency and the most representative outline chosen.The maximum glacier extent during the LIA was not reached simultaneously in Icelandbut many glaciers started retreating from their outermost LIA moraines around 1890. The total area of glaciers in Iceland in 2019was approximately 10 400 km^2, and has decreased by more than 2200 km^2 since the end of the 19th century (corresponding to an 18% loss in area) and by approximately 750 km^2 since~2000. The larger ice caps have lost 10–30% of their maximum LIA area, whereas intermediate-size glaciers have been reduced by up to 80%. During the first two decades of the 21st century, the decrease rate has on average been approximately40 $km^2\ a^{-1}$. During this period, some tens of small glaciers have disappeared entirely. Temporal glacier inventories are important for climate change studies, for calibration of glacier models, for studies of glacier surges and glacier dynamics, and they are essential for better understanding of the state of glaciers. Although surges, volcanic eruptions and jökulhlaups influence the position of some glacier termini, glacier variations have been rather synchronous in Iceland, largely following climatic variations since the end of the 19th century.

20igsnb3642

Arctic Monitoring and Assessment Program (AMAP) observational records indicating Arctic physical climate change

Jason Box

Corresponding author: Jason Box

Corresponding author e-mail: jbox.greenland@gmail.com

Student?No

This work distills a list of 'key climate signals' from a collection of 11 observational Arctic climate indicators. The temporal coverage is limited to 1971–2019 when the most precise records are available but encompassing the pronounced warming in Arctic climate beginning after the mid 1980s. The chapter articulates new insights relative to the SWIPA 2017 update and the work that summarized the observational records in the cross cutting chapter of that report. Each section articulates knowledge gaps and makes recommendations to enhance or maintain whichever record is considered vital for Arctic climate monitoring.

20igsnb3643

Glacial ripping in sedimentary rocks: insights from Cambrian quartzites at Loch Eriboll, NW Scotland

Adrian Hall, Hannah Mathers, Maarten Krabbendam

Corresponding author: Adrian Hall

Corresponding author e-mail: adrian.hall@natgeo.su.se

Student?No

Ripping is a newly-recognised process sequence in which glacial erosion is driven by groundwater overpressure. Recent investigations in gneiss terrain in lowland Sweden indicate that ripping involves three stages of (i) hydraulic jacking, (ii) rock disruption under subglacial traction and (iii) glacial transport of rock blocks. Evidence for each stage comes, respectively, from dilated fractures with sediment fills, disintegrated roches moutonnées and boulder spreads. Here we ask can glacial ripping also occur in sedimentary rocks, and what are its effects? The case study area is in hard, thin-bedded, gently-dipping Cambrian quartzites at Loch Eriboll, NW Scotland. Cosmogenic isotope ages indicate that the retreating margin of the last ice sheet stood at the mouth of Loch Eriboll at 17.6 ka. Field surveys reveal dilated, sediment filled, bedding-parallel fractures, water escape structures and brecciated quartzite masses that indicate pervasive, shallow penetration of groundwater at overpressure. Other features indicate glacial disruption and short distance transport, including disintegrated rock surfaces, boulder spreads and thick, monomict rubble tills. The field results indicate that glacial ripping operated with high impact close to the former ice margin. Glacial ripping thus can operate effectively in bedded sedimentary rocks and can be fundamental in till formation.

20igsnb3644

Basal conditions of Hagen Bræ

Øyvind Andreas Winton, Sebastian Bjerregaard Simonsen, Anne Munck Solgaard, Robert Fausto, Nanna Karlsson

Corresponding author: Øyvind Andreas Winton

Corresponding author e-mail: oew@geus.dk

Student?Yes

Basal conditions play an essential role in the dynamics of outlet glaciers but generally they cannot be observed directly. Inverse methods can be used to infer basal parameters from surface observations. Here, we use a simple ice-flow model as a forward model in an inversion scheme, to retrieve the spatial and temporal distribution of the basal stress parameter for Hagen Bræ, North Greenland. Hagen Bræ is a surge-type glacier with up to an order of magnitude variability in winter velocities. Much of the variability is likely caused by changes at the base of the glacier. We find that downstream changes in the basal stress can explain most of the variation of flow velocity, and we further identify a region of high resistance around 25-35km from the grounding line.

20igsnb3645

Thinning leads to calving-style changes at Bowdoin Glacier, Greenland

Eef van Dongen

Corresponding author: Eef van Dongen

Corresponding author e-mail: vandongen@vaw.baug.ethz.ch

Student?Yes

Ice mass loss from the Greenland Ice Sheet is the largest single contributor to sea-level rise in the 21st century. The mass loss rate has accelerated in recent decades mainly due to thinning and retreat of its outlet glaciers. The diverse calving mechanisms responsible for tidewater glacier retreat are not fully understood yet. Since a tidewater glacier's sensitivity to external forcings depends on its calving style, a detailed insight into calving processes is necessary to improve projections of ice sheet mass loss by calving. As tidewater glaciers are mostly thinning, their calving styles are expected to change. Here, we study calving behaviour changes under a thinning regime at Bowdoin Glacier, Northwest Greenland, by combining field and remote sensing data from 2015 to 2019. Previous studies showed that major calving events in 2015 and 2017 were driven by hydro-fracturing and melt-undercutting. New observations from UAV imagery and a GPS network installed at the calving front in 2019 suggest ungrounding and buoyant calving have recently occurred, as they show (1) increasing tidal modulation of vertical motion compared to previous years, (2) absence of a surface crevasse prior to calving, and (3) uplift and horizontal surface compression prior to calving. Furthermore, an inventory of calving events from 2015 to 2019 based on satellite imagery provides additional support for a change towards buoyant calving since it shows an increasing occurrence of calving events outside of the melt season. The observed change of calving style could lead to a possible retreat of the terminus, which has been stable since 2013. We therefore highlight the need for high-resolution monitoring to detect changing calving styles and numerical models that cover the full spectrum of calving mechanisms to improve projections of ice sheet mass loss by calving.

20igsnb3646

The PROMICE ice velocity product

Anne Solgaard, Anders Kusk

Corresponding author: Anne Solgaard

Corresponding author e-mail: aso@geus.dk

Student?No

We present Greenland wide ice-velocity maps from Sentinel-1 that are produced as part of the PROMICE project. The maps span two Sentinel-1 cycles (24 days) and are a mosaics of all possible 6 and 12 day pairs within that period. New maps are posted every 12 days as new data becomes available, and the product spans the period September 2016 to present. The data product is validated against time series of GPS measurements from Promice automatic weather stations distributed along the ice sheet margin. We discuss removal of noise from the maps and show maps and time series of data coverage.

20igsnb3648

Modeling the Antarctic firn

Nicolaj Hansen, Sebastian Simonsen, Ruth Mottram, Rene Forsberg

Corresponding author: Nicolaj Hansen

Corresponding author e-mail: nichsen@space.dtu.dk

Student?Yes

The regional climate model HIRHAM5 has been set up for running Antarctic simulations, as described in Mottram et al. 2020, who concluded that reliable subsurface schemes are important to get realistic surface mass balance (SMB) results, especially in West Antarctica.

Here, we use the HIRHAM5 outputs to force an offline surface mass balance model in two different versions to model Antarctic firn from 1980 to 2017.

The first version has a fixed layer thickness and in the second the layer thickness evolves by splitting or merging layers based on differences in temperature, density, grain size, water content, ice content, depth and thickness. The two versions also use different melting and refreezing schemes (Vandercrux et al. 2018). The model runs are validated against in situ observations of firn temperature and subsurface density. We find a mean temperature bias of 0.2–0.25°C and a mean bias in modeled density of –8.7±9.9 kg m^3 and 4.3 ± 11.2 kg m^3 for layers less than 550 kg m^3 and between -28.4±25.8 kg m^3 and –7.7 ± 21.7 kg m^3 for layers with a density above 550 kg m^3. How the layers evolve affect the modeled SMB in the period. SMB, in the evolving layer version, over the whole continent is estimated to be 2473.5±114.4 Gt a^{-1} while the fixed layer has a higher annual mean SMB of 2583.4±121.6 Gt a^{-1} . However, excluding the ice shelves gives a smaller difference of only 30 Gt (1963.3±96.2 Gt a^{-1} and 1995.4±99.3 Gt a^{-1} respectively for the grounded ice sheet only) demonstrating the importance of firn modeling in areas with substantial melt. Both SMB results are within the range of other models. However, the version with the evolving layers resolves finer details inside the firn, and better represents firn density profiles.

Finally, we investigate links between the southern annular mode (SAM) and SMB on an individual basin-scale using Monte Carlo simulation. There is a clear correlation in 13 out of 27 basins. In general, when SAM is positive there is a higher SMB in East Antarctica and a lower SMB in West Antarctica and the westerly side of the peninsula, and vice versa when the SAM is negative.

20igsnb3650

Modelling the climatic mass balance of three glaciers in Norway along a continentality gradient, 1961-2019

Kamilla Hauknes Sjursen, Thorben Dunse, Antoine Tambue, Thomas Vikhamar Schuler, Liss Marie Andreassen

Corresponding author: Kamilla Hauknes Sjursen

Corresponding author e-mail: kasj@hvl.no

Student?Yes

Glacier mass-balance and runoff models are useful tools to assess the impact of climate change on glacier evolution and the hydrological regime of glacierized catchments. Empirical temperature-index methods are often used to model glacier melt using climate reanalysis data, due to the lack of in-situ meteorological measurements required to simulate the full surface energy balance. Model parameters are calibrated based on a limited number of observations of mass-balance measurements and discharge records. The robustness of current parameter values for long term simulations and changing climate conditions has been challenged, raising doubts about the suitability of temperature-index models to predict future glacier and runoff evolution. We performed simulations of glacier climatic mass-balance for three glaciers (Nigardsbreen, Ålfotbreen and Storbreen) along a continentality gradient in southern Norway from 1961 to 2019. Engelhardt et al. (2014) simulated the climatic mass balance and discharge for the three catchments from 1961 to 2012 using a temperature-index method including potential direct solar radiation. We extend the simulations of climatic mass balance up to the latest mass balance measurements in 2019 and apply the same parameters and input dataset of gridded daily mean temperature and daily precipitation (seNorge version 1) as used in Engelhardt et al. (2014). We (1) discuss the changes in climatic mass balance on a decadal timescale and the meteorological drivers; and (2) evaluate the model performance considering the meteorological conditions throughout the simulation period.

20igsnb3651

Reconstruction of Late Quaternary glaciation in the Ahuriri River valley, New Zealand, based on geomorphological mapping and cosmogenic 10Be data

Levan Tielidze, Shaun Eaves, Kevin Norton, Andrew Mackintosh

Corresponding author: Levan Tielidze

Corresponding author e-mail: tielidzelevan@gmail.com

Student?Yes

Mountain glaciers are sensitive to variations in temperature and precipitation – thus records of their past changes yield important data concerning the timing and magnitude of past climate change. After the peak of the last glaciation (about 20 000 years ago), mountain glaciers began to retreat significantly with slight advancement phases from time to time. On the scale of several millennia, we have only very indirect observations of glacier retreat and advance based on the positions of glacial moraines. Well preserved moraines provide a good opportunity to develop an improved understanding of ice ages and glacial-interglacial transitions. Dating of the moraines using cosmogenic exposure techniques such as 10Be is providing exciting and important information on the duration, timing, and scale of the Late Quaternary glaciation (Last Glacial Maximum in particular), as well as providing additional information about the past climate.

Some valleys in South Island, New Zealand already have a number of well-dated glacier records. However, understanding of the precise timing of old glacial events in many valleys still remains poor.

We used field observation and geomorphological mapping to investigate the extent and drivers of glaciation in the Ahuriri River valley, Southern Alps, New Zealand. Cosmogenic ^{10}Be surface exposure dating technique was also used to constrain the timing and extent of late Quaternary glaciation in this valley. Numerical glacier modelling will be used later in order to investigate palaeo climatic implications for the study area.

20igsnb3652

Rock fracturing by subglacial hydraulic jacking in basement rocks, eastern Sweden: the role of beam failure

Maarten Krabbendam, Romesh Palamakumbura, Christian Arnhardt, Adrian Hall

Corresponding author: Maarten Krabbendam

Corresponding author e-mail: mkrab@bgs.ac.uk

Student?No

In eastern Sweden, dense networks of dilated fractures occur locally in the upper 5–10 m of bedrock in basement gneisses. Near Forsmark, pre-existing sub-horizontal fractures have been jacked open and filled with water-lain sediment, below the Fennoscandian Ice Sheet, likely during the latest phase of the Weichselian glaciation. Despite extensive previous research, it is uncertain whether subglacial jacking led to the generation of new, additional vertical fractures. Re-analysis of historic photos shows that rock fragments were broken off the main fracture surfaces, and mixed with sediment fill. Fracture analysis, applied to historic photos from excavations near the Forsmark power plant, shows that there is a higher density of vertical fractures above dilated sub-horizontal fractures, whereas a lower density of vertical fractures occurs above tight sub-horizontal fractures. Rare dilated sub-horizontal fractures, overlain by intact rock above, are invariably filled with sediments. We apply a model of beam failure theory, borrowed from structural engineering, and use assumptions based on measured water pressure fluctuations from beneath from the Greenland Ice Sheet. This modelling shows that beam failure is a plausible mechanism for the generation of new vertical fractures during a fluctuating water pressure cycle. This implies that jacking can result in further in situ disruption of the shallow rock mass below an ice sheet, but also that long dilated fractures can survive intact only if the sediment fill deposition occurred coeval with jacking. Altogether, hydraulic jacking and new formation of vertical fractures results in effective subglacial mechanical weathering of the shallow rock mass.

20igsnb3654

Seasonal-to-decadal geodetic mass balance of Hofsjökull, central Iceland, 1980–2020

Joaquín M.C. Belart, Tómas Jóhannesson, Romain Hugonnet, Robert McNabb, Etienne Berthier, Thorsteinn Thorsteinsson, Johann Stötter

Corresponding author: Joaquín M.C. Belart

Corresponding author e-mail: jmm11@hi.is

Student?No

Detailed time series of Digital Elevation Models (DEMs) are becoming available for most glacierized regions, mostly obtained from satellite observations, but often complemented with airborne surveys. In this study we present a dense time series of DEMs for Hofsjökull, central Iceland, obtained from declassified spy stereoimages (1980, n=1), aerial photographs (1987–99, n =3), SPOT5 stereoimages (2004, n =1), airborne lidar (2008–13, n =3), ArcticDEM (2013–17, n =202) and Pléiades stereoimages (2020, n =4). We use a novel approach to correct for horizontal and vertical bias of the ArcticDEMs, calculating ~2000 pairwise shifts between the possible combinations of ArcticDEMs in areas of overlap, and computing optimal absolute horizontal and vertical bias corrections. This results in a positional accuracy of each ArcticDEM strip within 0.5 m (vertical) and 1 m (horizontal). Overall, every location of Hofsjökull contains 10–15 elevation points in 2008–20, and 15–20 elevation points in 1980–2020. We applied Gaussian processes statistics in each 20×20 m cell of a stack of elevations and produced a spatially and temporally homogenized time series of DEMs, every month during 2008–20 and every year during 1980–2020. The derived geodetic mass balance of the ice cap is in good agreement with interannual variations according to glaciological mass-balance observations. The derived elevation changes are also in good agreement with the results of a global analysis of glacier elevation changes using the full ASTER archive for 2000–19. The presented methods will be applied to other Icelandic glaciers, and could be implemented for many other Arctic glaciers using openly available DEMs.

20igsnb3655

COLD – investigating ocean–ce interactions around the Antarctic Ice Sheet

Thomas Zwinger, Rupert Gladstone, Fabio Boeira Dias, John C. Moore, Petteri J. Uotila, Peter Råback

Corresponding author: Thomas Zwinger

Corresponding author e-mail: thomas.zwinger@csc.fi

Student?No

A Finnish consortium consisting of the Arctic Center at the University of Lapland, the INAR institute at the University of Helsinki and CSC-IT Center for Science in Espoo recently started new activities to improve the understanding of the interaction between the southern ocean and the shelf and land ice masses around and on the Antarctic continent. This presentation shall give insights on latest developments in oceanographic modelling, ice-sheet simulations and steps towards coupling these two components, using High Performance Computing (HPC) techniques. Latest development in the ocean model ROMS, with simulations covering the whole southern ocean and the impact of different resolutions on resolving warm water intrusions around the Antarctic shelves are discussed. We also show the initial development in the new generation ice sheet model, Elmer/Ice, to account for shear bands and vertical ice advection in the data assimilation process needed to obtain reasonable present day initial conditions, both, in velocities as well as temperature distributions. Finally, we show first results of coupled ROMS-Elmer/Ice simulations using the new ice sheet-ocean coupling framework FISOC.

20igsnb3656

Total Svalbard glacier mass balance 2013–17 from ArcticDEM data

Jack Kohler, Geir Moholdt, Ash Morris, Chris Nuth, Ward van Pelt

Corresponding author: Jack Kohler

Corresponding author e-mail: jack@npolar.no

Student?No

Svalbard is among the fastest warming regions on Earth, which has led to significant glacier loss. The latest estimate for the total mass balance over the two last decades is –8±6 Gt a^{-1}, but a small number of recent glacier surges have significantly impacted the total mass balance, making it desirable to update this estimate for the most recent period. Here we present analysis of Svalbard glacier elevation change using ArcticDEM strip products combined with updated frontal position changes to estimate the geodetic mass balance for Svalbard glaciers for the period 2013–17.

20igsnb3657

Constraining the relationship between velocity and basal traction over the grounded regions of Greenland

Nathan Maier, Florent Gimbert, Fabien Gillet-Chaulet, Adrien Gilbert

Corresponding author: Nathan Maier

Corresponding author e-mail: ntmaier@gmail.com

Student?No

On glaciers and ice sheets, constraints on the bed physics which control the relationship between velocity and traction are critical for simulating ice flow. However, in Greenland the relationship between velocity and traction remains unquantified over much of the ice sheet. In this work we determine the spatial relationship between velocity and traction in all eight drainage catchments of Greenland. The basal traction is estimated using three different methods over large grid cells to minimize biases associated with unconstrained rheologic parameters used in numerical inversions. We find that the velocity-traction relationships are consistent with our current understanding of basal physics in each catchment. We identify catchments that predominantly show Mohr-Coulomb-like behavior typical of deforming beds or significant cavitation, as well as catchments that predominantly show rate-strengthening behavior typical of Weertman-type hard-bed physics. Overall, the velocity-traction relationships suggest that the flow field and surface geometries over the grounded regions of the Greenland ice sheet are mainly dictated by Weertman-type physics. This data-based analysis provides a first constraint on the physics of basal motion over the grounded regions of Greenland and provides unique insight into future dynamics and vulnerabilities in a warming climate.

20igsnb3658

Glaciers in the critical zone: a proposal for an earth science observatory, Lyngen, north Norway

Brian Whalley

Corresponding author: Brian Whalley

Corresponding author e-mail: b.whalley@sheffield.ac.uk

Student?No

A 'critical zone' is the 'near surface environment in which complex interactions involving rock, soil, water, air, and living organisms regulate the natural habitat and determine the availability of life-sustaining resources'. As such, they represent a natural field of investigation for earth scientists at local and landscape scales. In North Norway they can be related to present-day glacial and cryic conditions and the effects of 'warming' environments.

This poster introduces a projected scheme for an integrated view of glacier presence and landform development and processes in North Norway. The Lyngen area (69° 40′N, 20°10′E) has glacier observations from the late 19thC to the present day from (cold-based) glacierized summit plateaus at 1600 m to near sea level. This altitudinal range allows the study of changing glacial-geomorphological-ecological conditions by linking glacial, periglacial, slope, fluvial and coastal processes to weathering and erosion and ecosystem shifts at varying catchment scales. Modern instrumentation and observational methods would enable monitoring over short and long time periods.

Study of this area would allow an observatory in an environment largely untouched by human activities and allow integration of process-based functional links in bio- and geo-diversity based on the critical zone concept. Thus, plateau glacier recession reveals blockfields that are being colonized by bacteria to lichen and alpine plants with associated weathering of gabbroic bedrock.

The Lyngen and Öksfjordjökelen areas of north Norway allow examination of present day and long-exhumed glacial critical zones on bedrock plateau surfaces (under permafrost and temperate conditions). The 'glacier critical zone' at the base of retreating glaciers reveals plateau blockfields, weathered to perhaps 0.5 m in ultrabasic rocks, show clay minerals developed from long-term exposure on the Norwegian Paleic surface (uplifted since the Miocene) that dips east towards Finland. Although weathered, blockfields are largely undisturbed by retreating glaciers, remnants of ice perhaps 1km above the present plateau. The maritime nature of this area allows comparison with more continental areas such as Tarfala in Sweden.

20igsnb3659

A sudden jökulhlaup from the newly formed marginal lake at Langjökull, W Iceland

Thorsteinn Thorsteinsson, Esther Jensen, Ingibjörg Jónsdóttir, Kristjana Eyþórsdóttir, Andri Gunnarsson, Hlynur Skagfjörð Pálsson, Oddur Sigurðsson, Finnur Pálsson, Ragnar Þrastarson, Gunnar Sigurðsson, Tómas Jóhannesson

Corresponding author: Thorsteinn Thorsteinsson

Corresponding author e-mail: thor@vedur.is

Student?No

Jökulhlaups from marginal and subglacial lakes are a considerable hazard in Iceland and the rapid retreat of glaciers and ice caps is leading to hydrological changes in many locations at or near the glaciers. This calls for careful monitoring of glaciers and proglacial areas. On 17 August 2020, increased discharge was observed in Hvítá, a glacial river originating in the ice cap Langjökull. Sediment-laden jökulhlaup waters filled a narrow gorge of the river near the farm and tourist resort Húsafell and dead salmon were found strewn over fields 30–40 km downstream. Several reconnaissance trips, overflights and satellite images revealed the following course of events:

A marginal glacial lake (current size: 1.3 km^2) has formed at ~900 m elevation at the western margin of Langjökull since the turn of the century. Outflow from the lake has hitherto entered a narrow gorge leading to lake Flosavatn 2 km further north. No unusual events have been observed in recent years. On 17 August at somewhat before 13:03, outflow had started from the (as of yet unnamed) marginal lake through a 2 km long subglacial water course. Emerging from beneath the ice cap, the water flowed 13 km through the Svartá river canyon, eroding sediment from the river bed and canyon walls. Fresh colouring and sediment deposition was observed on sandur plains where Svartá joins the Geitá and Hvítá rivers. On 17 August at 16:00, water level rose at the Kljáfoss hydrometric station on Hvítá, 53 km downstream from the glacier outlet. Rising from a discharge level of 90 $m^3 s^{-1}$ (a figure close to the long-term average), the flood peaked there at 260 $m^3 s^{-1}$ at 01:45 in the early morning of August 18. Flooding had subsided again at noon on 18 August.

Using imagery from the Sentinel-2 satellites the area of the marginal lake is estimated to have diminished from 1.29 km^2 to 0.46 km^2 during the jökulhlaup. A lowering of 5 m has been estimated from aerial imagery and the total volume released was 3.4 million m^3 according to preliminary estimates. From currently available data we estimate an average flow velocity of 3±1 m s^{-1} for the entire distance from the outlet at the glacier to Kljáfoss. Although damage due to this flood was minimal, the event highlights the need for careful monitoring of the marginal lake in the coming years. Such monitoring could involve a new hydrometric station on the Svartá river and possibly water-level measurements in the marginal lake.

20igsnb3661

Surface velocity by GPS in the Northeast Greenland Ice Stream (NEGIS): an assessment of interior ice velocity derived from satellite data

Christine S. Hvidberg, Aslak Grinsted, Dorthe Dahl-Jensen, Shfaqat Abbas Khan, Anders Kusk, Jonas Kvist Andersen, Niklas Neckel, Anne Solgaard, Nanna B. Karlsson

Corresponding author: Christine S. Hvidberg

Corresponding author e-mail: ch@gfy.ku.dk

Student?No

The Northeast Greenland Ice Stream (NEGIS) extends around 700 km from its onset near the ice divide to the coast in Northeast Greenland. We have mapped the ice velocity by GPS in an area located approximately 150 km from the ice stream onset near the EastGRIP deep drilling site (75°38′N, 35°60′W, 2700 m a.s.l.). A 63 stake network was established and observed by GPS for consecutive years in 2015–19. The area extends 35 km along the NEGIS and 40 km across, covering the 25 km wide fast flowing ice stream with a surface speed of 57 m a^{-1} and extending across both shear margins to the slower moving regions outside the ice stream. We compare the GPS results to the Arctic Digital Elevation Model and a list of satellite-derived surface velocity products from different sensors and sources in order to assess the accuracy of these products. For each velocity product we calculate the bias and the precision, and show that the best products have a bias and a precision of ~0.5 m a^{-1}. We discuss the derived flow lines and possible trends in the ice flow in these areas.

20igsnb3663

Reconstruction of early Holocene jökulhlaups along the Hvítá River and Gullfoss waterfall, Iceland, during Icelandic Ice Sheet retreat

Greta Wells, Þorsteinn Sæmundsson, Andrew Dugmore

Corresponding author: Greta Wells

Corresponding author e-mail: ghwells@utexas.edu

Student?Yes

Glacial outburst floods (jökulhlaups) have occurred across Earth throughout the Quaternary, leaving a geomorphologic, sedimentological, and climatic legacy that extends far beyond the source region and can persist for millennia. Iceland experiences more frequent jökulhlaups than nearly anywhere on Earth, though most research focuses on floods triggered by subglacial volcanic and geothermal activity. However, abundant evidence also exists in Iceland for non-volcanogenic floods from proglacial lakes, which may serve as a better analogue for most global jökulhlaups.

As the Icelandic Ice Sheet retreated across Iceland in the Late Pleistocene-Early Holocene, meltwater lakes formed at ice margins and periodically drained in jökulhlaups. Some of the most catastrophic floods drained from ice-dammed Glacial Lake Kjölur, surging across southwestern Iceland from the interior highlands to the Atlantic Ocean. These floods left extensive geomorphologic evidence along the modern-day course of the Hvítá River, including canyons, anastomosing bedrock channels, boulder deposits, and Gullfoss—one of Iceland's most famous waterfalls. The largest events reached an estimated peak discharge on the order of 10^5 m^3 s^{-1}, ranking them among the largest known floods in Iceland. Yet, all our evidence for the Kjölur jökulhlaups comes from only one publication from a quarter-century ago.

This project employs new methods to better constrain flood timing, routing, magnitude, and recurrence interval at this underexplored site. This presentation synthesizes geomorphologic field evidence, hydraulic reconstructions, and ongoing cosmogenic nuclide analyses to reconstruct flood dynamics and chronology. Specifically, it situates the Kjölur jökulhlaups within the context of Icelandic Ice Sheet retreat, incorporating new evidence and existing paleoenvironmental records to present a series of scenarios of ice margin position, glacial lake evolution, and jökulhlaup drainage. Finally, it assesses the Kjölur jökulhlaups as an analogue to past and contemporary glacial lake outburst floods in Arctic and alpine regions worldwide, where they pose an increasing risk to downstream communities due to climate-driven meltwater lake expansion.

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GEE4Snow: a support for better understanding of snow dynamics from space

Jie Zhang, Erik Jan Bootsma, Veijo Pohjola, Rickard Pettersson

Corresponding author: Jie Zhang

Corresponding author e-mail: zhangjie.bnu@gmail.com

Student?No

Under a changing climate, improved knowledge of snow dynamics is becoming increasingly important for climate studies and water resource management. Google Earth Engine (GEE) is a cloud-based and planetary-scale geospatial processing platform, enabling efficient investigations of snow dynamics at a large scale. Clouds present significant challenges for satellite-based snow detection, especially in the region where cloud cover is prevalent. In this work, by leveraging the big data and massive computation capacity of GEE, we implement a series of gap-filling algorithms on MODIS snow cover products to reduce the cloud contamination, aiming to develop improved snow cover and snow phenology products. In addition, the GEE generated snow phenology product will be further used to downscale the currently coarse-resolution snow water equivalent (SWE) product for better describing the spatial variability of snow mass. The developed products on snow presence, snow phenology and SWE can contribute to an improved understanding of the spatio-temporal dynamics of snow cover and snow mass. Although this work focuses on Sweden, the method is built upon GEE and can be easily adopted for applications in other regions of the world.