23NB_4425

An ocean model sea ice budget sensitivity in the Southern Ocean

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Sea-ice concentration (SIC) and volume (SIV) budgets synthesize many important air–sea–ice interaction processes. However, they are rarely skillfully simulated by Earth system models' ocean components. In this study, we investigated the sensitivity of 18 key NEMO4.0-SI3 (Nucleus for European Modelling of the Ocean coupled with the Sea Ice Modelling Integrated Initiative) parameters on SIC and SIV budgets in the Southern Ocean based on a total of 449 model runs and two global sensitivity analysis methods. We found that the simulated SIC and SIV budgets are sensitive to ice strength, the thermal conductivity of snow, the number of ice categories, two parameters related to lateral melting, ice–ocean drag coefficient and air–ice drag coefficient. An optimized ice–ocean drag coefficient and air–ice drag coefficient reduced the root-mean-square error between simulated and observed SIC budgets by about 10%. This implies that more precise sea-ice velocity is the key to optimizing the SIC budget. We recommend 10 combinations of NEMO4.0-SI3 model parameter values, as they improve the modelled sea-ice extent. This work has been published as Nie, Y, Li, C, Vancoppenolle, M, Cheng, B, Boeira Dias, F, Lv, X & Uotila, P (2023) Sensitivity of NEMO4.0-SI3 model parameters on sea-ice budgets in the Southern Ocean, Geoscientific Model Development, vol. 16, no. 4, pp. 1395-1425, doi:10.5194/gmd-16-1395-2023.

23NB_4426

Estimation of distributed committed ice loss in the European Alps until 2050 using a deep-learning-aided 3D ice-flow model with data assimilation

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Modelling the short-term (<50 years) evolution of glaciers is difficult because of issues related to model initialisation and data assimilation. However, this timescale is critical, particularly for water resources, natural hazards, and ecology. Using a unique record of satellite remote-sensing data, combined with a novel optimisation and surface-forcing-calculation method within the framework of the deep-learning-based Instructed Glacier Model, we are able to resolve initialisation issues. We thus model the committed evolution of all glaciers in the European Alps up to 2050 using present-day climate conditions, assuming no future climate change. We find that the resulting committed ice loss exceeds a third of the present-day ice volume by 2050, with multi-kilometre frontal retreats for even the largest glaciers. Our results show the importance of modelling ice dynamics to accurately retrieve the ice-thickness distribution and to predict future mass changes. Thanks to high-performance GPU processing, we also demonstrate our method's global potential.

23NB_4428

Simulating the Southern Ocean with a Physical-Biogeochemical Model

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Simulating the Southern Ocean with a Physical-Biogeochemical Model

23NB_4429

Increasing stable time-step sizes of ice-sheet- and glacier simulations

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Numerical simulations of the evolution of glaciers and ice sheets within a full-Stokes model requires solving a non-Newtonian and highly viscous flow problem coupled to the so-called free-surface equation. This coupled system is relatively stiff and therefore subject to a strict time-step size constraint. In general, time-step sizes complying with the stability restriction is much smaller than the natural time scale at which glaciers and ice sheets evolve. One possible way of speeding up simulations is therefore to stabilize the coupled system and employ larger time-step sizes. A stabilization method meeting this end is the free-surface stabilization algorithm (FSSA), originally developed for mantle-convection simulations, but has been used with success also for stabilizing ice-dynamical simulations. In this work the FSSA is made available to a large community of ice-sheet modelers by implementing it into the widely used full-Stokes ice-sheet solver Elmer/Ice. The method is demonstrated by performing prognostic simulations of the Midtre Lovénbreen glacier, Svalbard, where it is found to increase stable time-step sizes by at least a factor of two without significant impact on the accuracy of the solver. Furthermore, the method is found for simulations on two-dimensional synthetic glacier domains to increase stable time-step sizes by a factor of five to ten - depending on the steepness of the glacier surface.

23NB_4430

Effects of Arctic sea-ice concentration on turbulent surface fluxes in four atmospheric reanalyses

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A prerequisite for understanding the local, regional, and hemispherical impacts of Arctic sea-ice decline on the atmosphere is to quantify the effects of sea-ice concentration (SIC) on the turbulent surface fluxes of sensible and latent heat in the Arctic. We analyse these effects utilising four global atmospheric reanalyses: ERA5, JRA-55, MERRA-2, and NCEP/CFSR (CFSR and CFSv2), and evaluate their uncertainties arising from inter-reanalysis differences in SIC and in the sensitivity of the turbulent surface fluxes to SIC. The magnitude of the differences in SIC is up to 0.15, but typically around 0.05 in most of the Arctic over all four seasons. Orthogonal-distance regression and ordinary-least-square regression analyses indicate that the greatest sensitivity of both the latent and the sensible heat flux to SIC occurs in the cold season, November to April. For these months, using daily means of data, the average sensitivity is 400 W m-2 for the latent heat flux and over 800 W m-2 for the sensible heat flux per unit of SIC (change of SIC from 0 to 1), with the differences between reanalyses as large as 300 W m-2 for the latent heat flux and 600 W m-2 for the sensible heat flux per unit of SIC. The sensitivity is highest for the NCEP/CFSR reanalysis. Comparing the periods 1980–2000 and 2001–2021, we find that the effect of SIC on turbulent surface fluxes has weakened, owing to the increasing surface temperature of sea ice and the sea-ice decline. The results also indicate signs of decadal-scale improvement in the mutual agreement between reanalyses. The effect of SIC on turbulent surface fluxes arises mostly via the effect of SIC on atmosphere-surface differences in temperature and specific humidity, whereas, the effect of SIC on wind speed (via surface roughness and atmospheric-boundary-layer stratification) partly cancels out in the turbulent surface fluxes, as the wind speed increases the magnitude of both upward and downward fluxes.

23NB_4434

Cold-climate collapse of the Eurasian Ice Sheet driven by glacial-lake outburst

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The evolution of paleo ice sheets to past climate fluctuations helps contextualize the response of contemporary Polar ice sheets to ongoing atmospheric and ocean forcing. In this presentation, results of modelling and marine geophysics from the Eurasian Ice Sheet (EIS) - the third largest Quaternary ice mass - demonstrate that ice sheet dynamics triggered by a glacial lake outburst forced its abrupt collapse within ~1800 years. The glacial lake that occupied the Pechora Sea during the last glaciation, drained the northeastern flank of the EIS and with a volume of ~90,000 km^3 was - albeit briefly - Earth's largest freshwater body. As Ice Lake Pechora grew, hydraulic gradients forced subglacial discharge westward beneath the ice saddle that dammed it, eroding a network of 2 km-wide tunnel valleys into bedrock. When this saddle eventually breached ~16,000 years ago, the ensuing glacial lake outburst flood directly contributed ~6 cm to global sea level rise, but also split the Barents Sea sector of the EIS from its Fennoscandian counterpart. This fragmentation effectively doubled EIS seaboard exposure to the incursion of warmer ocean circulation, driving enhanced calving and submarine melting that resulted in its subsequent collapse. This study identifies contingent thresholds within the ice-ocean system capable of driving abrupt deglaciation, even during cold - Heinrich 1 Stadial - conditions, standing as a prescient analogue for the potential non-linear dynamics underpinning marine sectors of Greenland and Antarctica.

23NB_4435

Stochastic Simulations of Bed Topography Constrain Geothermal Heat Flow and Subglacial Drainage near Dome Fuji, East Antarctica

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Subglacial topography controls local to catchment-scale glacial and subglacial processes and is a persistent source of uncertainty in investigations of basal ice temperature, subglacial melting, water flow and ponding. We used stochastic simulation methods and radar data to generate an ensemble of bed topography grids with the continuous, realistic roughness necessary to assess basal conditions near Dome Fuji, East Antarctica, which is one of few regions where 1.5-Ma old ice could be preserved for investigating the mid-Pleistocene climate transition. Ensemble analysis reveals the magnitude and spatial distribution of topographic uncertainty, facilitating uncertainty-constrained assessments of subglacial drainage and topographic adjustments to geothermal heat flow. We find that topographic variability can lead to widespread local geothermal heat flow variations of ± 20% the background value, which aggregate to raise the regional value and suggest previously underestimated distributions and rates of basal melting. We also find that survey profile spacing has an increasing influence on topographic uncertainty for rougher bed, deriving an empirical relationship that could guide future survey planning based on uncertainty tolerance.

23NB_4436

Enhanced methane emissions due to glacial retreat in the high Arctic

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Permafrost and glaciers in the high Arctic form an impermeable 'cryospheric cap' that traps a large reservoir of subsurface methane, preventing it from reaching the atmosphere. Cryospheric vulnerability to climate warming is making releases of this methane possible. On Svalbard, where air temperatures are rising more than two times faster than the average for the Arctic, glaciers are retreating and leaving behind exposed forefields that enable rapid methane escape. We undertook a field survey of unprecedented spatial coverage across central Svalbard to identify methane emission hotspots in glacial forefields, a previously unknown emission source. Here we document how methane-rich groundwater springs have formed in recently revealed forefields of 78 land-terminating glaciers, bringing deep-seated methane gas to the surface. Waters collected from these springs during February–May of 2021 and 2022 are supersaturated with methane up to 600,000 times greater than atmospheric equilibration. Spatial sampling reveals a geological dependency on the extent of methane supersaturation, with isotopic evidence of a thermogenic source. We estimate annual methane emissions from proglacial groundwaters to be up to 2.31 kt across the Svalbard archipelago. Our findings reveal that climate-driven glacial retreat facilitates widespread release of methane, a positive feedback loop that is probably prevalent across other regions of the rapidly warming Arctic.

23NB_4437

Ice thickness of the Antarctic Peninsula Ice Sheet north of 70ºS

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The glaciers on the Antarctic Peninsula (AP) play an important role in ocean dynamics, global climate, and ecology. During recent decades, the AP has become an important contributor to sea-level rise. Despite this, the ice discharge, mass balance, and total volume of the region remain unclear. Motivated by this uncertainty about the ice-thickness distribution, we used a finite element method to infer the ice thickness in the Antarctic Peninsula Ice Sheet north of 70ºS applying a two-steps approach. The first step uses two different assumptions, namely, the shallow ice approximation (SIA) and the perfect plasticity (PP). The second step then uses the mass conservation equation to estimate the thickness in fast-flowing regions, with the aim of overcoming the limitations of SIA and PP near the glacier termini. Manual adjustment of glacier outlines and new ways to deal with rheological parameters along the margins provided further improvements. The application of the model at our study site resulted in a total ice volume of 28.7 ± 6.8 10^3 km^3 and an ice discharge of 95.0 ± 14.3 km^3 a^{-1}.

23NB_4439

What can we learn from the artificial drainage of the proglacial lake of Bossons Glacier?

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The retreat of glaciers often leads to the formation of proglacial lakes in the recently deglaciated bed depressions, posing a potential risk to infrastructure and people living in the valleys downstream. In some cases, these lakes can be partly ice-dammed and hazards are then either related to a sub or intra-glacial channel opening, a wave overtopping the glacier, the breakoff of the ice dam or an overflow in a supraglacial channel when the ice freeboard vanishes. Interestingly, the latter overflow can be provoked as the solution to safely drain the lake by the incision of a supraglacial channel. As there are very few data on the processes governing the deepening of such supraglacial channel, predictions of expected peak discharge and rate of incision during the lake drainage suffer large uncertainties, making difficult the operational decision to use such solution. In this talk, after having presented the context of the Bossons lake, I will describe the instrumentation deployed during its artificial drainage of August 2023 and the inputs that can be gained in term of our understanding of supraglacial channel incision.

23NB_4440

Sources of Elemental Carbon in a 300-Year Svalbard Ice Core

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Black carbon (BC) particles produced by incomplete combustion of biomass and fossil fuels warm the atmosphere and decrease the reflectivity of snow and ice, hastening their melt. Although the significance of BC in Arctic climate change is widely acknowledged, observations on its deposition and sources are few. We present BC source types in a 300-year (1700–2005) Svalbard ice core by analysis of particle-bound organic compounds, radiocarbon, and trace elements. According to the radiocarbon results, 58% of the deposited elemental carbon (EC, thermal-optical proxy of BC) is of non-fossil origin throughout the record, while the organic compounds suggest a higher percentage (68%). The contribution of fossil fuels to EC is suggested to have been elevated between 1860 and 1920, particularly based on the organics and trace element data. A second increase in fossil fuel sources seems to have occurred near the end of the record: according to radiocarbon measurements between 1960 and 1990, while the organics and trace element data suggest that the contribution of fossil fuels has increased since the 1970s to the end of the record, along with observed increasing EC deposition. Modeled atmospheric transport between 1948 and 2004 shows that increasing EC deposition observed at the glacier during that period can be associated with increased atmospheric transport from Far East Asia. Further observational BC source data are essential to help target climate change mitigation efforts. The combination of robust radiocarbon with organic compound analyses requiring low sample amounts seems a promising approach for comprehensive Arctic BC source apportionment.

23NB_4441

How does geometry affect outlet glacier response to runoff?

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How does geometry affect outlet glacier response to runoff?

23NB_4442

Multi-sensor airborne observations of Arctic sea ice

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Sea-ice thickness is a key factor and indicator in understanding the impact of the global climate change. Deriving basin-wide sea-ice thickness estimates from satellite laser and radar altimetry relies on freeboard measurements. The freeboard-to-thickness conversion in turn requires information of snow mass and the density of the sea-ice layer that have unknown spatio-temporal variabilities and trends directly translating into the uncertainty of decadal sea-ice thickness data records. In addition, inter-mission biases arise from, e.g., different sensor types and frequencies as well as varying footprint sizes affected by surface roughness across regions and seasons. Therefore, carrying out validation and inter-calibration studies is crucial for reliable and continuous observation of the Earth's cryosphere. To achieve this, it is beneficial to have simultaneous measurements of freeboard, snow depth, and sea-ice thickness, which provide reference data for both direct satellite observations and geophysical target parameters. Here, I present the IceBird program by the German Alfred Wegener Institute (AWI). It is a series of fixed-wing aircraft campaigns to measure Arctic sea ice and to monitor its change. During late-winter campaigns in the western Arctic Ocean since 2017, surveys have been carried out with a unique scientific instrument configuration including an airborne laser scanner for surface topography and freeboard measurements, a tethered electromagnetic induction sounding instrument (EM-Bird) for total (snow+ice) thickness measurements, and an ultrawideband frequency-modulated continuous-wave microwave radar to measure snow thickness. Therefore, it is possible to observe all three bounding interfaces in the sea-ice–snow system in high resolution along survey tracks on regional scales. The individual parameters are important for describing and monitoring the state of the Arctic sea ice and validation studies, but combined they offer further possibilities to characterise sea ice. By assuming isostatic equilibrium, it is possible to estimate up-to-date bulk density values for different sea-ice types and to derive a parametrisation of sea-ice bulk density based on sea-ice freeboard. I conclude the presentation by giving a short summary of recent advancements in radar-derived snow depth retrieval methods and an outlook on current projects and future prospects regarding the abovementioned data.

23NB_4443

Downslope winds are responsible for spatial variation of supraglacial lakes in Dronning Maud Land

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Several studies on Antarctic Ice Shelves have reported significant spatial variability of supraglacial lakes. Identifying factors responsible for the observed supraglacial lake behaviour is essential for a better understanding of the processes surrounding surface meltwater systems and for improving our ability to model and project future lake evolution, mass loss and sea level rise. As Antarctica is huge with potentially variable factors influencing the behaviour of meltwater lakes, we narrow our focus to a smaller region in Antarctica - Dronning Maud Land (Longitude 15°W-35°E) - to identify the factors driving their spatial distribution. Reportedly, five ice shelves in this region have ponded meltwater with large spatial variability – namely (from highest to lowest area) Roi Baudouin (304.82 ± 90.94 km2), Nivlisen (65.85 ± 15.55 km2), Riiser Larsen (33.54 ± 14.66 km2), Muninisen (2.43 ± 1.09 km2) and Fimbulisen (1.64 ± 0.55 km2). Relationship assessment, between the lake extents and various climatic factors, performed using outputs from the regional climate model MAR (Modèle Atmosphérique Régional, run at a spatial resolution of 5 km) reveals that downslope winds are largely responsible for the spatial distribution of lakes in the region. In this study, we find the first evidence of foehn occurrences in Dronning Maud Land caused due to ice rises and promontories which act as topographic barriers. While these winds are frequent and pronounced on Riiser Larsen and Roi Baudouin, katabatic winds are strong and frequent along the eastern Dronning Maud Land Ice Shelves – Nivlisen and Roi Baudouin. The occurrence of both foehn and katabatic winds over the Roi Baudouin Ice Shelf (particularly in the east) explains the large pool of surface meltwater seen over the ice shelf. These downslope winds cause surface scouring leading to exposure of blue ice and thereby triggering the melt-albedo feedback in addition to the adiabatic warming and vertical mixing of air. Downslope wind speeds surrounding Fimbulisen and Muninisen are reduced by the exposed rock outcrops, which results in lower meltwater generation and surface ponding in these areas. This work provides important insights into the drivers of supraglacial lakes and must be further expanded to the larger Antarctic continent for a holistic understanding of Antarctic supraglacial lakes.

23NB_4444

The rocky side of IceBio – Exploring subglacial nutrient release and rock crushing

Klara Koehler, Beatriz Gill Olivas, Martyn Tranter, Alexandre Anesio

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The poster introduces the IceBio Doctoral Network, and one of 12 PhD Projects which examines subglacial rock crushing and nutrient release. IceBio is funded by the Horizon European Marie Skłodowska-Curie Actions, and the 12 PhD students are located at seven different institutes across Europe. The network aims to explore the glacial biome holistically, and so includes studenships examining atmospheric inputs and surface processes, subglacial processes, glacial runoff and the impact of glaciers on downstream ecosystems. IceBio strives for a deeper understanding of microbial and biogeochemical processes in the cryosphere, emphasising the nutrient and energy sources that fuel the glacial ecosystem, and the possible positive and negative feedbacks that microbial processes in the cryosphere might have on global warming. The PhD project, "Glacial flour, grinding and nutrient release", is one of the 12 IceBio studentships, and will study nutrient release in the subglacial environment. It will focus on the nutrient content and energy sources that are released by rock crushing via field and laboratory studies. This poster presents the first research questions addressed in this projectintroduces the different sampling areas and the first laboratory experiments.

23NB_4445

Investigating the effect of snow-ice formation on snow depth and density over Arctic sea ice

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This study examined the effect of snow-ice formation on SnowModel-LG snow depth and density products. We coupled SnowModel-LG, a modeling system adapted for snow depth and density reconstruction over sea ice, with HIGHTSI, a 1-D thermodynamic sea ice model. Pan-Arctic model simulations were performed over the period 1 August 1980 through 31 July 2022. We compared snow depth and density from the coupled product (SnowModel-LG_HS) to the original outputs of SnowModel-LG. In SnowModel-LG_HS, domain average snow depth decreased and snow density increased when compared to SnowModel-LG. The differences were much larger in the Atlantic sector. Averaged across the CryoSat-2 era (2011-2022), domain average sea ice thickness retrievals from CryoSat-2 decreased significantly when snow-ice was accounted for. SnowModel-LG_HS results were evaluated against Arctic observations of snow depth, snow-ice and sea ice thickness. The evaluation highlighted the importance of snow redistribution over deformed sea ice. Our simulations suggest that when snow-on-sea-ice models do not account for snow and sea ice interactions, such as snow-ice formation and snow redistribution over deformed sea ice, snow depth over level ice can be remarkably overestimated.

23NB_4446

Towards the limits of life on Earth: the Jutulsessen Blue Ice Ecosystem, Antarctica

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Antarctic Blue Ice Areas (BIAs) constitute just 1.67% of the Antarctic ice sheet surface, or 235,000km2. However, since they promote sub-surface melting, they function as hotspots for hydrological, biological and biogeochemical processes on an otherwise cold, inhospitable ice sheet surface. This presentation describes our study at Jutulsessen, where we applied a combination of remote sensing, ground sampling and radiative transfer modelling to quantify an entire blue ice ecosystem at an unprecedented spatial scale. In so doing we compare the high altitude, inland Jutulsessen BIA with better-known low altitude BIAs and the extensively studied Dry Valley glaciers. We describe how subsurface melt at Jutulsessen creates an expansive sub-surface hydrological system connecting a surprisingly dense network of debris-filled cryoconite holes, covering up to 14% of the ice surface. High concentrations of nutrients evolve in these holes, because the aqueous products of rock-water-microbe interactions are concentrated by solute rejection during refreezing and vapour deposition onto the underside of the ice lid that forms over the holes. As a consequence, the holes store a significant 420 kg km-2 of aqueous nutrients (NO3+NH4+PO4) and 660kg km-2 of dissolved organic carbon. Whilst the cryoconite holes are host to a range of bacterial communities, including the "usual suspects" reported elsewhere in Antarctica, the ice surrounding the holes is almost barren of life. As a consequence, there exists a complete dependence upon cryoconite holes for biological production across the BIA ecosystem. We also suggest that damage by UV light is important, because it is very likely to reduce the success of microbes within ice as it enters the "Goldilocks Zone" and both light and liquid water become available. By contrast, protection from harmful UV is easily afforded by the debris in the cryoconite holes. Cryoconite holes have been hitherto overlooked by quantitative studies of melt water production and drainage system development in Antarctic BIAs. However, the volume of water storage we documented in them was equivalent to a 19 mm water layer across Jutulsessen BIA. The role of BIAs in the provision of melt water, nutrients and inocula for transport to downstream environments is therefore going to be important as we seek to understand the consequences of warming in Antarctica.

23NB_4448

Modelling ridging on local scales using discrete element methods

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When sea ice is moved by wind and currents, ice ridges can form either due to compression or shear. Ridging on local scales is a factor influencing the strength of the larger-scale sea-ice field. However, the relation of ridging forces on local scale and the ice strength, for example used in contemporary Earth system models, on large scale remains unclear. To investigate ridging of sea ice in detail, we use the Aalto University in-house three-dimensional discrete-element- method model. As the deformable, multi-fracturing, ice floes come into contact, they deform and fail forming ridges. During the simulations, we can gauge ridging forces and make detailed observations on ridging processes. We validated our model in laboratory scale by showing that ridging load values from the simulations fit measurements from experiments performed in the Aalto Ice and Wave tank. Additional full-scale simulations show that Cauchy-Froude scaling can be applied to ridging forces.

23NB_4449

Svalbard tidewater glacier retreat

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No abstract!

23NB_4450

Ice thickness and volume of all Scandinavian glaciers and ice caps

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We present a new ice thickness map and volume estimate for all glaciers and ice caps in Scandinavia. We apply a novel thickness inversion method that leverages global satellite products in combination with an ice flow model and calibrate our results against >10,000 thickness observations. As part of our methodology, the Instructed Glacier Model (IGM) is used which is a Convolutional Neural Network (CNN) trained on the inputs and outputs of a full-Stokes model, allowing to emulate full-Stokes-like ice physics at low computational cost. We find a total Scandinavian ice volume of 321 km^3 with an uncertainty range between 287 and 364 km^3. The distributed thickness maps are the first to show ice-dynamically realistic flow features for both ice caps and glaciers.

23NB_4451

Hyperspectral Data Analysis of Mittivakkat Glacier Using Specarray, a New Python Package

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Hyperspectral Data Analysis of Mittivakkat Glacier Using Specarray, a New Python Package

23NB_4452

Sedimentation provides temporary stability for premature retreat of Taku Glacier, Alaska

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Taku Glacier was in the advance phase of the tidewater glacier cycle from ~1890 to 2015. In the tidewater glacier cycle, terminus advance is enabled by the continual redistribution of an end moraine, which limits mass losses due to frontal ablation and promotes thickening via resistive stresses. As the terminus advances the mass balance eventually becomes negative due to lengthening of the ablation area, leading to thinning and retreat from the end moraine. Rapid calving retreat ensues as the terminus retreats into deep water, and retreat continues until the terminus reaches a pinning point. The cycle then begins anew. This cycle can be explained entirely in terms of ice dynamic processes and can occur in the absence of climate variability. In contrast, our observations at Taku Glacier suggest that the glacier's current retreat is a result of of climate change. The retreat began prior to the glacier exhausting it's sediment supply, and consequently sediment continues to be deposited at the terminus as the glacier retreats and retreat is proceeding relatively slowly. These observations suggest that the loss of stability during transition to tidewater glacier retreat depends on whether the retreat is initiated by ice dynamics or changes in climate.

23NB_4453

Calving variability on Hansbreen (Svalbard) using time lapse images

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Calving variability on Hansbreen (Svalbard) using time lapse images

23NB_4454

Triggers of the 2022 Larsen B multi-year landfast sea ice break-out and Hektoria Glacier's rapid retreat

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In late March 2011, landfast sea ice (hereafter, 'fast ice') formed in the northern Larsen B embayment and persisted continuously as multi-year fast ice until January 2022. In the 11 years of fast ice presence, the northern Larsen B glaciers developed extensive mélange areas and formed ice tongues that extended up to 16 km from their 2011 ice fronts. Fast ice breakout began in January 2022, and was closely followed by retreat and break-up of both the glacier mélange and the adjacent ice tongue areas. Here, we show the probable triggers for the loss of fast ice and document the initial upstream glacier responses. Our results suggest that the fast ice loss was linked to strong wave action (>1.5 m amplitude) with long period swells (>5 s) that reached the embayment simultaneously with the appearance of widespread rifting in the fast ice, coinciding with an open sea ice corridor in the northwestern Weddell Sea. Remote sensing data in the months following the fast ice break-out reveals an initial ice flow speed increase (up to 333%), elevation loss (9 to 11 m), and rapid calving of floating and possibly grounded ice for the three main glaciers Crane (11 km), Hektoria (25 km), and Green (18 km). Furthermore, we investigate the heretofore unseen pace of tidewater-style glacier retreat of Hektoria Glacier. Two and a half months after the initial fast ice break-up, an abrupt change in Hektoria's calving style was observed, changing from large tabular icebergs to buoyantly rotated smaller bergs. Following this transition, Hektoria underwent several short periods of rapid retreat, for example; in December 2022 2.5 km of grounded ice were lost over 2.5 days. These retreat rates for grounded tidewater ice are greater than any reported in the modern glaciological record. We examine the drivers that could cause such a rapid retreat and tie them to known glacier instabilities, such as Marine Ice Sheet Instability and Marine Ice Cliff Instability, as well as the typical tidewater glacier retreat cycle.

23NB_4455

Iceberg collisions triggering large calving events in Dronning Maud Land, East Antarctica

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Iceberg calving is a main driver of Antarctica's ice-sheet mass balance, accounting for almost half of mass loss. Large tabular calving events represent the majority of the total volume of all Antarctic icebergs. However, studying such events is particularly challenging due to their unpredictability and infrequency. Here, we used eight years of satellite imagery spanning from 2014 to 2022 to study annual changes in ice shelf extent and related tabular calving events in the Dronning Maud Land region of East Antarctica. The results reveal that most of these events occurred in 2021 and were initiated by collisions with drifting icebergs from the east. The first major collision involved an iceberg from the Amery Ice Shelf, triggering a series of subsequent collisions with newly formed icebergs. Consequently, this chain reaction led to a substantial loss of ice-shelf area, amounting to approximately 2700 km2, a stark contrast to the median annual area gain of 360 km^2 observed in previous years of data.

23NB_4456

Changes in firn properties and meltwater retention on Austfonna ice cap based on observations and model simulations

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The Arctic is warming at a greater rate than the global mean, and resulting increase in melt and net mass loss from glaciers and ice caps is contributing to global sea-level rise. Mass loss from runoff is influenced by meltwater retention in firn (compressed multi-year snow) through refreezing or storage in perennial firn aquifers. Meltwater retention in firn can buffer runoff; conversely, formation of thick near-surface ice layers can limit percolation and accelerate mass loss. Although refreezing is known to play an important role in the mass balance of Svalbard glaciers, the retention processes in frozen and liquid forms and their changes under warming climate are not well understood. Here, these processes are investigated on the Austfonna ice cap, Svalbard, with observational data and model simulations. Firn stratigraphy and density from 16 firn cores drilled near the summit of the ice cap (750-791 m a.s.l.) spanning from 1958 to 2022 are evaluated. The firn stratigraphy consists mainly of thin ice layers; thus, ice slabs (> 1 m layers) that have recently been found in Greenland, are not present on the ice cap. Firn density and ice content decreased during 2005-2012, a period of below average melt, indicating a replenishment of firn pore space. The firn temperature record at site Camp (773 m a.s.l.) from 2009 to 2022 reveals a shift in the firn thermal regime in 2014 or 2015, from typically cold firn to fully temperate firn except for seasonal cooling. Simulations using the CryoGrid community model at site Camp from 2003 to 2022 confirm the thermal shift, and results suggest a formation of a seasonal firn aquifer in 2004, 2020 and 2022. Simulated firn cold content and pore space in the upper 10 m decrease significantly 2008-2022. However, simulated refreezing is not found to be decreasing, which may partly be due to model limitations leading to inaccurate simulation of the amount of melt.

23NB_4458

High-resolution analysis on sea-ice observations

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Sea-ice deformation exhibits scale-invariance and multifractality in statistical analysis indicating a highly nonlinear system described by congruent scaling laws. Even though the lower bound of this scale invariance is analytically estimated at the scale of ice thickness, previous research has been restricted to scales magnitudes larger. In response to the gap in high resolution empirical data, we develop a learning-based observation framework for retrieval of deformation estimates at near pixel-scale with small temporal intervals in radar imagery. To demonstrate the performance of the algorithm, we analyze ice-radar data gathered during MOSAiC expedition.

23NB_4459

New data collection to constrain the glacio-hydro(geo)logical conceptual model of temperate glaciers South-East Iceland in modelling perspective

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Temperate glaciers losing mass due to anthropogenic climate change, remain poorly constrained in terms of en-glacial and sub-glacial water fluxes and their impact on groundwater resources. The outlet glaciers of Vatnajökull in South East Iceland (from Breiðamerkurjökull to Fláajökull) are ideal to observe and improve understanding of this dynamic. Improvements are needed for the glacio-hydro(geo)logical conceptual model of these temperate glaciers that have over-deepening at the bed and are located in maritime climate. The aim of the study is to characterize the subglacial and englacial drainage systems at different elevations on the glaciers; that is the observed features and their seasonality, quantify the water flows and the proportions flowing within each water pathway. The instrumentation and new data collection carried out during the last melt season is presented. Various experiments were carried out, including: dye tracing on Skálafellsjökull and Breiðamerkurjökull to quantify water velocities, channel type and seasonality; passive seismic recordings over a few days on Skálafellsjökull to characterize channel type during the melt season, but also in the vicinity of rivers to characterize the surface flow of these rivers as they leave the glaciers and also time-lapse cameras to obtain continuous recordings of water flow. Simulations of meltwater input (ablation models), precipitation (climate models) and satellite observations of ice flow velocity over the study period are currently being gathered. The need for a coupled model simulating subglacial and groundwater flow will be presented, as well as the modeling strategy for future studies based on the collected data.

23NB_4461

The Greenland mass loss in a warmer world - the last interglacial

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The Parallel Ice Sheet Model (PISM) is used to build up a glacial Greenland ice sheet and simulate the evolution of the Greenland ice sheet through glacial terminations, focusing on previous warmer climates, the Eemian and the Holocene thermal maximum. During the Holocene, surface elevation changes derived from ice cores suggest a large thinning in the north, suggesting that the Greenland ice sheet was connected to the North American ice sheet in Canada during the last glacial. By including Canada in the modelling domain this thinning in the early Holocene, as the connecting ice bridge broke up, will be investigated.

23NB_4462

The coupled evolution of crystal orientation fabric and ice flow in ice streams

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The evolution of grain orientations (fabric) as a function of flow in polycrystalline glacier ice can greatly affect the bulk viscous anisotropy of ice, and hence mass loss from Earth's large ice sheets through fast-flowing ice streams where such affects are thought to be important. This project seeks to build a vertically-integrated, anisotropic, numerical ice-flow model of an idealized ice stream. The overall aim is to test the poorly-understood (or hypothesized) effects of fabric-induced viscous anisotropies on ice streams, such as along-flow hardening and shear-margin softening. Model results will be compared with ice-core and radar-derived fabric profiles available for the North-East Greenland Ice Stream (NEGIS). This poster focuses on changing the grain orientation of a discrete sample of grains and turning this discrete model into a spectral model.

23NB_4463

Spatial variability of Arctic sea-ice albedo during the freeze-up period from drone-based observations

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The dramatic change in the sea-ice albedo occurring during the Arctic freeze-up period was captured by surface-based and airborne observations carried out during the last leg of the MOSAiC expedition (August-September 2020). The time series of sea-ice albedo measured from the FMI ground-based station installed over a melt pond offered a close-by look onto the evolution of the melt-pond albedo, while the drone-based observations provided insight on how the density distributions of the surface albedo varied in time over the horizontal scale of few hundred meters. Despite the challenge of measuring extremely small irradiances mostly in overcast conditions and with the sun being only few degrees above the horizon, the data enabled characterizing the seasonal progress of the density distributions of the sea-ice albedo resulting from the coexistence of the various surface features (melt ponds, leads, ridges and scattering ice), and how those distributions depend on the instrument footprint (height above the surface). The study improves our understanding of the uncertainties that arise from satellite validation over heterogeneous Arctic sea-ice when point-to-pixel comparisons are made between in-situ and remotely sensed datasets representing different scales. Furthermore, it will contribute to develop statistically based surface descriptors that will better represent the sea-ice albedo in coarser scale climate models, which are used to understand and predict the forthcoming changes in the new Arctic.

23NB_4464

A3D-DEM ice mechanics modeling tool

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Discrete element model describing three-dimensional failure process of an ice sheet is introduced. The presented model is based on discrete element method. The ice sheet consists of polyhedral rigid discrete elements joined by a lattice of Timoshenko beams, which go through a cohesive softening process upon failure. Inter-particle friction and local failure of ice in contacts is accounted for. The model has been validated against a laboratory experiments with a good agreement found between the modelled and experimental failure process.

23NB_4466

Modeling the Greenland ice sheet Holocene thinning

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Over the past 11,700 years, the Greenland ice sheet has experienced substantial thinning, with some regions losing up to 600 meters of ice. Geological evidence, including moraine lines in western Greenland, suggests that the ice sheet once extended far beyond its current boundaries, possibly reaching the continental shelf. To comprehend these historical changes and their driving factors, we employ a Bayesian framework with a three-dimensional Parallel Ice Sheet Model (PISM). In this study, we utilize climate data derived from ice cores to inform our model, allowing us to simulate the observed changes in the Greenland ice sheet's geometry.

23NB_4467

New research with the versatile Canadian Ice Island Drift, Deterioration and Detection (CI2D3) Database

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"Ice islands" are large, tabular icebergs that calve from ice tongues and ice shelves in both Polar Regions. These extreme ice features pose potential risk to marine industry, and, through their drift and deterioration, ice islands can have climatological impacts given their role in dispersing freshwater originating from the Greenland and Antarctic ice sheets. The Canadian Ice Island Drift, Deterioration and Detection (CI2D3) Database was generated through a partnership between the Water and Ice Research Lab at Carleton University and the Canadian Ice Service (Environment and Climate Change Canada) to unlock opportunities for unique research programmes of ice-island dynamics and detection. The database is a rich and comprehensive dataset of ice-island observations, containing over 25,000 geospatial records of tracked ice islands that were identified in over 4,400 satellite synthetic aperture radar scenes. The CI2D3 Database has been utilised in 4 peer-reviewed articles to date, with two additional manuscripts currently under review. This presentation will introduce the database and detail two recent studies in which it was utilised. The first study concerns the representation of the buoyancy-driven "footloose mechanism" in the modelling of ice-island deterioration. Using size and lineage information of ice islands tracked in the database, the performance of an ice-island deterioration model was quantitatively assessed through simulating the length and areal change of 172 ice islands. With the footloose mechanism represented, the mean error in simulated length change was +15 (+/- 400) m over 20 d. This increased to +401 (+1400/-800) m for simulations that ran to 80 d. This performance is a substantial improvement compared to simulations that included thermal melt but not fracture. A simple, two-parameter approach to modelling ice-island areal change resulting from the footloose mechanism is also presented. The second study employed the CI2D3 Database to detect ice-island grounding locations. Utilising conservatively deep estimates of ice-island keel depth, potentially erroneous depths in two gridded bathymetric products were identified. The presentation will conclude with discussion of ongoing and upcoming work with the database, which includes ingesting records of ice islands that recently calved from the Milne Ice Shelf of Ellesmere Island.

23NB_4469

Terrain factors influencing the distribution of snow in a mountain landscape – a UAV technology approach

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Abstract tba

23NB_4470

Reconstructing mass balance of glaciers in Norway using machine learning

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In recent years, machine learning (ML) models have emerged as a promising approach to model regional-scale glacier mass balance, demonstrating flexibility and strong predictive power. We investigate the capability of ML-models to generalize across glaciers and climatic settings from relatively sparse data by employing an ensemble tree-based model (XGBoost) to reconstruct glacier mass balance over the Norwegian mainland from the 1960s to present. We use an extensive dataset of around 4000 annual, summer and winter point mass-balance measurements from glaciological investigations on 32 glaciers, representing the variety of glaciers and climatic settings in Norway. In model training, we employ a blocking-by-glacier cross-validation strategy which respects spatial autocorrelation in the mass-balance data and provides robust and realistic performance evaluation by ensuring independence between training and validation data. Preliminary results from cross-validation show good model performance for the typical glacier hypsometry of glaciers in Norway (ranging from 800 to 2000 m a.s.l.) and an overall mean absolute error (MAE) of 1.00, 0.77 and 0.62 m w.e. for annual, summer and winter mass-balance, respectively. However, results also reveal poor performance in modelling ablation on low-lying glacier tongues where observations are limited to two locations, indicating that training data may be insufficient for the model to learn relationships between ablation, climate, and topography in this particular setting. Nevertheless, since only a handful of glacier tongues are situated within this elevation range, we expect the model to provide accurate mass-balance estimates for the majority of glaciers in Norway that can be used in future glaciological, hydrological and ecological applications.

23NB_4472

A web portal for measurements and information about Icelandic glaciers

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A new web portal about Icelandic glaciers (www.icelandicglaciers.is) was opened in 2022 to make glaciological measurements, historical photographs and various information about glaciers available to the public, scientists, students, the media and others. The portal is a collaborative effort by several Icelandic institutes involved with glacier studies. The portal displays measurements of glaciers and glacier variations as well as an overview of glaciological research. The portal provides access to regular glaciological measurements and observations that are carried out in Iceland, and the database of the portal is regularly updated with new observations. The glacier web portal publishes terminus measurements and data about the extent and mass balance of Icelandic glaciers, as well as numerous historical and overview photographs. Many pairs of comparison photographs provide striking visual evidence for the dramatic glacier changes that have taken place during the last century or more. The meteorologist Jón Eyþórsson started systematic measurements of glacier termini in Iceland around the year 1930 and enlisted local and lay people to carry out annual observations. Volunteers of the Icelandic Glaciological Society have carried out the measurements since the establishment of the society in 1950. The mass balance of Vatnajökull (from 1992), Hofsjökull (from 1988) and Langjökull (from 1997) and Mýrdalsjökull (from 2007) is measured annually. The outlines of glaciers at different times have been created by many scientists on the basis of aerial images, satellite images, maps and lidar DEMs of glaciers and glacier forelands. Glacier margins have also been traced by GPS-measurements and by observations of glacier moraines and other glacio-geomorphological field observations. Outlines of the main Icelandic glaciers at eight different points in time since the end of the 19th century are available in the portal. The outlines are updated approximately every second year and work is ongoing to include ice-marginal lakes in the outline data set in accordance with the GLIMS standard. Graphs, data and photographs made available on the glacier web portal are published according to a CC-BY license (Creative Commons Attribution 4.0 International License, "http://creativecommons.org/licenses/by/4.0") and the portal provides an option to download most of the data in digital format.

23NB_4473

On different SIA formulations and the related numerical instabilities

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The shallow ice approximation (SIA) equations ignore certain physical aspects like normal and shear stresses in both the viscosity function and the momentum balance. The simplification is based on the assumption that an ice sheet is thin. Originally, the SIA equations are obtained as a system of partial differential equations (PDEs) on strong form. However, it's also possible to express them on weak form. We conducted a computational study of the SIA equations using two different weak formulations: (i) we neglected the normal and shear stresses in both the viscosity function and the momentum balance, (ii) we only neglected these stresses in the viscosity function. We show numerically that in some cases the formulation in (ii) leads to less oscillatory velocities. We also present initial results on increasing the time step size when the SIA equations are coupled to the free-surface equation: we tested a free-surface stabilization algorithm (FSSA) previously introduced to the nonlinear Stokes problem formulation by Löfgren et al.

23NB_4474

Frontal ablation modulated by hydropower regulation: a case study from Austdalsbreen, Western Norway

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[REQUEST to host: I kindly ask you to schedule my contribution on Wednesday afternoon, after 1pm, or anytime Thursday - I will have to leave on Friday morning. Thank you] ----------- ABSTRACT: Austdalsbreen is a lake-terminating outlet glacier of the Jostedalsbreen Ice Cap in Western Norway. Since completion of a dam in 1988, the glacier calves into the Styggevatn hydropower reservoir, which is subject to significant water-level variations in the range of 1120 to 1200 m a.s.l. Since 1988, the glacier terminus has retreated by about 720m and changed characteristics from a predominantly land-terminating glacier to an active calving glacier. Here we present two years of timelapse photography capturing the glacier terminus of Austdalsbreen. Simultaneous measurements of water level, surface-air temperature and precipitation allow us to study the role of hydropower regulation and meteorological conditions in modulating seasonal variations in terminus dynamics and frontal ablation.

23NB_4475

Glacimarine sedimentation in Trygghamna, Svalbard

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Glacimarine sedimentation in Trygghamna, Svalbard

23NB_4477

Delineation of the Milne Glacier grounding zone using in-situ and satellite observations over 1966-2023

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Milne Glacier is a marine-terminating glacier located on the northern coast of Ellesmere Island, Canada a region that has experienced extensive ice-mass loss over the last two decades. Milne Glacier flows into Milne Fiord where it transitions from grounded to floating at a boundary known as the grounding zone. The glacier rests on a retrograde slope and is vulnerable to enhanced basal melt that triggers grounding zone retreat. Monitoring of changes here is required for a full understanding of glacier ice dynamics since the characteristics in this zone determine the rate at which ice flows from the grounded part of the glacier. In this study, we quantify changes in the Milne Glacier grounding zone from 1966 to 2023 using in-situ and satellite observations. Pairs of Synthetic Aperture Radar (SAR) images acquired between 1992 and 2023 from European Remote Sensing (ERS-1/2) satellites, Sentinel-1 A/B, and RADARSAT Constellation Mission (RCM) were combined into interferograms to delineate the grounding zone over this period. RCM-derived data provided the highest spatial resolution of 10 m and high coherence between 4-day repeat acquisitions, which resulted in the most continuous across-glacier delineation of the landward limit of the grounding zone known as the hinge line. We discovered that the grounding zone retreated up to ∼1 km along the glacier's centre line and up to ∼2 km along its western margin between 1992 and 2023. We also analyzed in-situ ice penetrating radar data collected between 2014 and 2023 to calculate the bed-reflection power (BRP) coefficient to distinguish between basal reflections from water versus grounded bed. This alternate way of delineating the grounding zone was in good agreement with our satellite-based SAR interferometric results. Analysis of historical airborne radar surveys in 1966 and 1981 in conjunction with our more recent BRP and satellite-derived positions revealed ∼3 km retreat in the grounding zone along the glacier centerline over the past 5+ decades. This analysis of grounding zone retreat over the last half century will serve as a baseline from which future cryospheric change can be compared as the Arctic climate warms.

23NB_4479

Double reflections in birefringent ice reveal orientation and strength of ice fabric

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The orientation of ice crystals within large ice masses has a strong influence on its mechanical properties. Under sustained deformation, the crystals start to reconfigure into a preferred orientation fabric that can soften or stiffen ice considerably. Because ice is a birefringent material and the electromagnetic properties and mechanical properties are closely linked, we can infer the crystal orientation fabric from polarized radar measurements. Here we will show a new and simple approach to determine the orientation and strength of the fabric from a polarized radar survey conducted at the North East Greenland Ice Stream in 2022.

23NB_4480

GC-Net - challenges of real-time in-situ monitoring of ice sheet surface mass balance

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The mass balance of glaciers and ice sheets has a significant impact on current and future global sea level rise. Understanding the physical processes behind the mass balance requires in-situ observations, which are scarce in the harsh and remote parts of the Arctic, including the Greenland Ice Sheet. Furthermore, the increasing accessibility and geopolitical importance of the Arctic highlights the need for observations available in near real-time, for improvement of weather forecast and extreme conditions. Here I present recent developments in instrumentation and data processing from the Danish-Greenlandic monitoring programme Greenland Climate Network (GC-Net), which delivers near real-time observations from the accumulation zone of the Greenland Ice Sheet. Apart from free access to data, the open access technical solutions developed in sustained glaciological monitoring programmes as GC-Net can be leveraged to benefit shorter-term research projects.