Online | 4–8 May 2020

Chat CR5.9 - Transcript

Subglacial Environments of Ice Sheets and Glaciers
Convener: Adam Booth | Co-conveners: Robert Bingham, Christine Dow, Bryn Hubbard, Harold Lovell

Adam Booth, Leeds (CONVENOR) (09:35) Good morning everyone - and welcome to CR5.9. Convenors are just setting up the environment, and we'll be kicking off very shortly!
RobBingham UEdinburgh (covenor) (09:37) Morning all, very excited about the next 2 hours
Marie Cavitte UCLouvain (09:42) Good morning all!
Olaf Eisen, AWI (CR PG) (09:42)
Good morning everybody,

some general info for the CR-led sessions for Mon-Thr:

- until now, more than 2/3 of the abstracts have displays, for some sessions even 85%

- we have more than 2200 active individual users

- about 240 comments were posted in the persistent "Discussion" part of the abstracts

A great thanks to all conveners for making this happen, and the users for active participation and bringing (and keeping) the community together in these times!

Enjoy the last day!

Emma Smith - AWI (author) (09:43) Hello all! Glad to see a fair few people have made it through to the Friday.
Adam Booth, Leeds (CONVENOR) (09:45)
Welcome to our session CR5.9 – Subglacial Environments of Ice Sheets and Glaciers! Not quite what we were planning for its relaunch this year, but thanks very much to the EGU for facilitating this arrangement and to you, our contributors, for staying involved!

Adam Booth, Leeds (CONVENOR) (09:45)
I would also take this time to apologise for the various changes that have gone on surrounding this session – we're all finding out feet a little bit with what works and what doesn't. We'll promote 'live' talks from our invited contributors next week, outside of the EGU programme, and you can join if you're able. If you're not able, we'll record their talks anyway so that you can watch and interact at your leisure.

Adam Booth, Leeds (CONVENOR) (09:45)
So, on with proceedings! Hopefully you'll have been in other sessions, and know the general way it works, but just to recap:

Adam Booth, Leeds (CONVENOR) (09:45)
All convenors in this session have "(convenor)" typed after their name. Their text appears in red, yours in blue, and other contributors in grey. If a convenor types STOP at any point, please stop typing and discussing – this is just to keep the session to time! Every author will get a time slot of ~4 minutes to discuss their material.

Adam Booth, Leeds (CONVENOR) (09:46)
A convenor will introduce each author, and the author should then introduce their work by typing a few sentences in the chat (which we hope you will have pre-prepared!).

Adam Booth, Leeds (CONVENOR) (09:46)
The virtual floor will then be opened for questions. Please direct your questions to the appropriate speaker using an @ symbol, and their name or the abstract ID. I'd also direct the audience to any uploaded materials that contributors have provided, which you can see next to this chat tool.

Adam Booth, Leeds (CONVENOR) (09:46)
Time is regrettably short for extended discussions, but we'd like to encourage you to continue your discussions with the commenting function linked to each display. EGU are keeping this facility open until 31st May 2020.

Adam Booth, Leeds (CONVENOR) (09:46)
Any questions on this before we begin?

Adam Booth, Leeds (CONVENOR) (09:47) Ok, I guess not! - thanks everyone for attending, let's crack on with the session!
Adam Booth, Leeds (CONVENOR) (09:47)
Our first contribution, I think, will be given by Silvia Frisia but doesn't appear to have any supporting material uploaded. Is there anyone online able to talk to this presentation?

Roland Warner University of Tasmania (09:47) @Adam - where will you post re the presentations next week?
Adam Booth, Leeds (CONVENOR) (09:48) Hi Roland - we'll advertise this in due course, when we have sorted it out. Sorry, still a bit on shifting sands!
Adam Booth, Leeds (CONVENOR) (09:49) Ok, so we now move on to D2305, and I invite @Ugo Nanni from Grenoble to introduce his work. @Ugo, the floor is yours!
Ugo Nanni - U. Grenoble Alpes (author) (09:49)
Good morning everyone, In this study we map the **spatio-temporal evolution of the subglacial drainage** system of an Alpine glacier using on-ice **seismic** observations. We also compare our spatio-temporal evolution with the subglacial hydraulic properties and glacier velocity.

We are capable to capture both the **distributed and the channelized drainage** system and the transition from a cavity-dominated to a channel-dominated drainage system during the early melt season. Our approach can be easily applied over other glacier/ice sheet and cryoseismology gives unique insights on the subglacial environments.

You can find a 1 min audio summary of our work on our display (or here https://soundcloud.com/user44994492/egu-nanni-2020).

Adam Booth, Leeds (CONVENOR) (09:50) Thanks @Ugo, and I now open cyberspace to questions!

Emma Smith - AWI (author) (09:50) @Ugo - fantastic presentation, I loved listening to the sound of the glacier! Would this type of seismic approach also be useful in a glacier with a more stable hydrological configuration - or is the strength of the method in the fact it the system and flow-rates change over time?

Andreas Alexander UiO (09:50) @Ugo. Very nice work. Do you have an estimation about the minimum number of seismometers you would need?

Louis Couston BAS (author) (09:50) @Ugo: related question to @Emma. Could this be useful for inferring water circulation in stable subglacial lakes?

Basile de Fleurian UiB (09:51) @ Ugo. Great work, You talk about extending to new glaciological contexts, Are there anylimitation on the method in term of ice thickness or valley geometry?

Ugo Nanni - U. Grenoble Alpes (author) (09:52)
@Emma. We choose the early melt season to capture the early stage of the subglacial hydrology, but our approach will work to capture the drainage system even if it has a stable configuration as it still generate tremor.

Rob Storrar SHU (09:53) @Ugo, this is great. Related to the other questions, is the density of the array (£/$) you need proportional to the expected size of the drainage channels?

lai bun lok LancasterUni (attendee) (09:53) Hi Ugo, what is the minimum spatial resolution of mapping that you get ?

Ugo Nanni - U. Grenoble Alpes (author) (09:54) @Andreas. The number of seismometer has to be high enough to have a sub-wavelength coverage so no more than c. 100/200 m between seismometers. I think that even with c. 20 seismometers you can starts to map the configuration of the drainage system.

Emma Smith - AWI (author) (09:54) @Ugo - thanks! I was thinking about applying these methods to existing data sets from Anatrctica maybe!

Adam Booth, Leeds (CONVENOR) (09:55) Thanks very much for this flurry of questions - thanks for the active chat! @Ugo, please feel free to carry on responding. However, I would now invite the contribution from @Louis Couston from BAS - Louis, the floor is yours.

Louis Couston BAS (author) (09:55)
Hi all! In this work, we considered subglacial lakes (SL) that are stable (i.e. not active) and with a flat ice-water interface/ceiling. The only forcing mechanism for water circulation is then the geothermal flux, F.

We investigated whether most or all SL in Antarctica should have a geothermally-driven water circulation. Our key findings are:

1) yes, **most SL should have a geothermally-driven water circulation**, regardless of ice pressure, pi, and for water depths, h > few meters (F~50mW/m^2 is large enough)

2) **characteristic water velocities** of geothermal-driven circulation scale ~linearly with water depth and **can reach 1cm/s** for 1km water depth (e.g. Vostok)

Note that 1) was not obvious because of *nonlinearity of equation of state* (density) with temperature at small ice pressure.

Note that 2) has implications for suspension of particulates/existence of biome.

Happy to take questions or hear comments that could help make our work relevant/applicable to your interests!

Adam Booth, Leeds (CONVENOR) (09:56) Thanks @Louis - I open the floor!
Roland Warner University of Tasmania (09:56) @Ugo - is there a separation (fequencies?) between the subglaical flow source and seismic signals from glacier basal sliding?
Rebecca Schlegel Swansea (author) (09:56)
@Louis, can you say a bit more what a unstable lake “looks” like, what makes it unstable. And What would happen if a lake switches from stable to unstable?

Andrew Wells, Oxford (09:57)
@Louis Very interesting - the vertical transport is presumably of particular significance for transport and mixing.

Do you know roughly what kind of Rayleigh, Rossby and Ekman numbers we might expect for this setting?

Louis Couston BAS (author) (09:58) @Rebecca: I was making the distinction with active subglacial lakes, ie part of a network and drainage system. for these lakes you can have external forcing (drainage from an upstream lake). our motivation is really to predict if we can have mixing in isolated lakes to support a biome.
Ugo Nanni - U. Grenoble Alpes (author) (09:58)
@Andreas, then it also depends on the geometry of the glacier and the drainage system.

@Basile. I think the biggest limitation is from the ice thickness as the greater the distance from the seismometer the larger the uncertainties. But for ice sheets as the subglacial channels might be larger this could compensate the large ice thickness. For the valley geometry I would say that there are not much limitations, our study case was quite in a narrow valley and side effects (e.g. reflections of waves) did not empeach us to map the subglacial drainage system. For larger setup this would also require more seismometers, but today it is quite easy to deploy hundreds of these little seismometers (nodes)

Rebecca Schlegel Swansea (author) (09:59) @Louis sorry I have to ask again, so stable=active?
Louis Couston BAS (author) (09:59) Thanks @Andrew. Ra can go up to the 10^20 and Ro is typically order 1. We re assuming rotation is negligible for simplicity but it would need to be refined
Louis Couston BAS (author) (10:00) @Rebecca. more like the opposite :) stable=not active. ie the water stays in the lake for very long (like millions of years)/never drains
Rebecca Schlegel Swansea (author) (10:00) @Louis, ok that makes more sense, thanks!
Adam Booth, Leeds (CONVENOR) (10:00) Thanks everyone! I'll now invite the contribution from the AWI's @Steven Franke. @Steven, please hit ENTER :)
Ugo Nanni - U. Grenoble Alpes (author) (10:00) @Louis. Yes, this could be usefull to study also subglacial lake. My only concern would be that water flow in subglacial lake might be "quiet" with very little turbulences, and therefore do not produce enough water tremor to be studied. But I think that this could be use to monitor the input/output of the lakes. In our previous study we also proposed to use the seismic amplitude to directly estimate the water discharge in the subglacial environnement.
Steven Franke, AWI (author) (10:00) In May 2018, AWI recorded some very nice radar data with their ultra-wideband radar in Greenland around the current EGRIP drill site, which

is located at the onset of the Northeast Greenland Ice Stream. What started in as an exercise at the Karthaus Summer School 2019 developed to a detailed analysis of the basal characteristics, which we infer from our radar data. We performed a spectral roughness analysis as well as an analysis on the bed return power and abruptness on profiles parallel and perpendicular to ice flow. Also, with a new bed elevation model, we could test how sensitive the basal water routing is to variations of bed slopes in comparison to the BedMachine bed topography. We conclude that at the onset, the ice stream can accelerate easily due to a smooth and increasingly lubricated bed. Further downstream, the ice stream widens, basal water preferably flows along the shear margins, and the terrain is getting rougher.

Adam Booth, Leeds (CONVENOR) (10:01) Thank you! Questions from chat-world, please?

Rebecca Schlegel Swansea (author) (10:02) @Steven what are you assuptions for effective pressure for the basal water routing?

Nanna B Karlsson, GEUS DK (10:02) @Steven What are the typical wavelenghts of roughnesses? I am thinking compared to local ice thickness

Andrew Wells, Oxford (10:02) @Louis Thanks. So very strong convection, but in an interesting regime with regard to the importance of Coriolis forces.

Steven Franke, AWI (author) (10:03) @Rebecca: As far as I know there are no assuptions been made on effective pressure. Only where water could flow along if it would be there.

Ugo Nanni - U. Grenoble Alpes (author) (10:03) @Rob, yes the density of the array (and thus the cost) is proportional to the expected size of the draiange system. During our study we run some tests to see the required number of seismometers for a given configuration, and I would be happy to share this with you. Actually we will soon submit the related paper and I will keep in mind to include such estimation nb seismometer/glacier geometry.

Steven Franke, AWI (author) (10:04) @Nanna: Good question. The information we got from the spectral roughness method is rather what frequency dominates in vertical and horizontal roughness. But that sould be something worth looking into. Good point :)

Tom Jordan, Bristol (10:04)
Nice work @ Steven! – Do you use radar reflectivity/`water hits' to constrain the flow routing or are they performed separately?

Adam Booth, Leeds (CONVENOR) (10:05) Thank you @Steven! Our next contribution is one of two invited 'talks', from @Jade Bowling at Lancaster. As I say, we will be sceening and recording Jade's talk at some time next week so do look out for updates. But for now, let's have it in text-form, @Jade!

Jade Bowling, Lancaster (PhD Student) (10:05)
Thanks Adam! Hi everyone, hope you are all well! I'm Jade, a PhD student at Lancaster University.

Long story short: we have found two collapse basin-like features in Northern Greenland which we suggest are caused by subglacial lake drainage.

Method: We developed a tool which calculates standard deviation of elevation using high-resolution (2 m) digital elevation models (ArcticDEM). We use this tool to detect ice surface anomalies on an ice-sheet scale.

Preliminary Results: The features are both on the downstream side of large obstacles and close to the ice margin where the ice is quite thin. They are >50 m deep which is similar to active lakes in Antarctica, but they are only 1.3 and 1.8 km^2 respectively. Feature 1 (Brikkerne Glacier) exhibits an unusual crevasse field and a raised linear feature which we think could be a channel.

We are currently exploring different datasets to assess our hypothesis and investigating whether there is an effect on ice flow. We'd be interested to hear your thoughts, and I am happy to answer questions in the chat, or feel free to email j.bowling@lancaster.ac.uk

Liz Bagshaw, Cardiff (author) (10:06) @Steven - love this. You say 'smooth, increasingly lubricated bed' - can you tell if it's a hard or soft bed from your method?
Ugo Nanni - U. Grenoble Alpes (author) (10:06) @ Iai Bun, here we have a resolution down to c. 1m. This arise from the fact that we perform thousands of location and then estimate probability location, doing increase the resolution beyond the wavelength limitations. For instance we locate crevasses with very high sub-meter precision.
Adam Booth, Leeds (CONVENOR) (10:06) Thanks @Jade - questions from the floor?
Louis Couston BAS (author) (10:06) @Ugo: thanks. well our work suggests there could be relatively strong convection in lakes. not sure if 1cm/s velocity is large enough. otherwise I was thinking of applying this for polar oceans under ice shelves. I will reach out by email.
Nanna B Karlsson, GEUS DK (10:06) @Jade It looks like the lakes in your study are close to the margin and probably not connected to a large subglacial system - is that correct? So they mainly interact with downstream waterflow like a glacier-lake outburst but subglacially?
Steven Franke, AWI (author) (10:06) @Nanna: But compared to wavelength we observe that vertical roughness is smaller when ice thickness is greater and higher when ice thickness is smaller. The horizontal wavelength is larger when ice thickness is smaller.
Liz Bagshaw, Cardiff (author) (10:07) @Jade - similar question to Nanna: how far from the margins do you detect them? Fantastic work, really enjoyed the paper
Adam Booth, Leeds (CONVENOR) (10:07) Thanks @Jade - could I ask what you think the source of the water for the charge/recharge is?
Louis Couston BAS (author) (10:08) @Jade. It seems you have detected about 50 lakes in Greenland, is this right? Is this new study aimed at refining their characteristics? Do you expect to have both active and stable lakes in Greenland?
Ugo Nanni - U. Grenoble Alpes (author) (10:09) @Roland. The subglacial water flow signature is around [3-10] Hz with a continuous signal. The stick-slip signature related to basal sliding cover a wide range from 5 to 400 Hz, but as the events are very-short lived we limit their influence in our amplitude-driven investigation. We also made a catalog of most of the basal-sliding related events and it appears that at our study site their are pretty rare, so they are not expected to influence much our location of water flow.
Steven Franke, AWI (author) (10:09) @Tom: Hi Tom, we didn't use the reflectivity to constrain water routing (like you did). We modelled potential water flow paths using the hydropotential. But we tried to compare if the water routing pathways coincide with high reflectivity. Unfortunately water routing runs along the shear margins where the attenuation is very high and reflectivity is not significantly higher in comparison to the local environment.
Ugo Nanni - U. Grenoble Alpes (author) (10:10) @Emma, Feel free to contact me about applying that to existing data sets from Antarcttica.

Jade Bowling, Lancaster (PhD Student) (10:10) @Nanna @Liz thanks for your questions, yes these new features are really close to the margin where the ice is thin. We suspect water could be ponding on the lee side of the nunatak, potentially trapped by a subglacial ridge, and then the subglacial lake bursts suddenly causing the ice surface to collapse. So yes like an outburst but subglacially. That's our current theory anyway :)
Emma Smith - AWI (author) (10:10) @Ugo - thanks I will!
Adam Booth, Leeds (CONVENOR) (10:11) Thanks everyone for the discussion! The next abstract is our second invited contribution - we'll be recording something of a double act from @Mike Prior-Jones and @Liz Bagshaw in the next week. However, for now, @Mike - type away!
Rob Storrar SHU (10:11) @jade really nice to see these features emerging. You mention apparent washing of the ice surface of the one in N Greenland. Is there a possibility of over-pressurised water draining supraglacially?
Mike Prior-Jones, Cardiff Uni (author) (10:11)
Thanks Adam. Good morning everyone!

Cryoegg is a wireless subglacial probe that we've developed, primarily for observing subglacial hydrological conditions. It measures temperature, water pressure, and electrical conductivity (the latter being a proxy for total dissolved solids). It's a 120mm sphere (size and weight of a large grapefruit) and intended to travel freely in subglacial channels, pushed along by the water. It makes measurements and then immediately transmits them to the surface by radio.

I joined the project in 2019 and did a complete redesign, with a new radio technology. I'm pleased to say that it's performed very well, working down to 1.3km in the EastGRIP ice core borehole, and we also got very good performance in temperate ice on the Rhone Glacier in Switzerland. The EC sensor also allows us to use Cryoegg for salt dilution gauging and we've demonstrated this in a moulin on the Rhone. We're currently doing a re-design to resolve issues with leaks and further improve both the radio range and battery life. The aim is to collect hourly data from 2.5km down for more than two years.

Steven Franke, AWI (author) (10:12) @Liz: Hi Liz, no, unfortunately, we can not. But we know from a publication from Christianson et al 2014, who did seismics in a small area around the drill site that deformable sediment is located in the center of the ice stream. This could be an indication that upstream of the drill site there is probably also soft sediment, because the roughness looks similar.
Adam Booth, Leeds (CONVENOR) (10:12) Thanks @Mike - the floor is open (thankfully, virutally...)
Emma Smith - AWI (author) (10:13) @Mike what is the distance range of these devices?
Rebecca Schlegel Swansea (author) (10:13)
@Mike: Is the cyroegg buoyant, like in a channel does it swim at the top, I can imagine it crashing with many obstacles then? And how many have you lost so far?

Olaf Eisen, AWI (CR PG) (10:13) @Jade: on ice shelves in Antarctica we more often see collapsing (ice)dolines = supraglacial. Could you potentially distinguish between subglacial outbursts and doline drainage and then collapse with your approach/ArcticDEM?
Andreas Alexander UiO (10:13) @Mike Interesting and nice work. You write you are planning to get through 2.5 km of ice. Usign the same frequency and a bigger antenna or do you have to change frequency?

Jade Bowling, Lancaster (PhD Student) (10:13) @Adam I suppose this is linked to Nanna's question, probably a combination of surface and subglacial water flow collecting downstream
Mike Prior-Jones, Cardiff Uni (author) (10:13) @Emma: it varies with the medium, but in cold ice it's at least a kilometre. in temperate ice it's less.
Mark Johnson Gothenburg Author (10:14) @Mike price tag on the Cryoegg?
Adam Booth, Leeds (CONVENOR) (10:14) @Mike, if I may - is the transmission affected by crevasses, and does it matter if they're water/air filled?
Juan Pedro Roldan-Blasco IGE (atendee) (10:14) @Mike Very interesting. Do you plan to recover them or assume they are going to be lost in the ice?
Mike Prior-Jones, Cardiff Uni (author) (10:14) @Rebecca - no, it's not buoyant. Weighs about 1.2kg, so the idea is to have it sit on the bottom. We've lost one so far, in a moulin in Greenland.
Rob Storrar SHU (10:14) @Mike, these are fantastic. How accurately can you track their location (XYZ)? Is this done via radar?
Andreas Alexander UiO (10:15) @Mike: And one more: How do you think your transmission distance will change, once the Cryoegg moves freely around, e.g. turbulence in channels and so on?
Mike Prior-Jones, Cardiff Uni (author) (10:15) @andreas thank you! we will use the same frequency but we need to improve the transmit antenna design, which is very inefficient at the moment.
Tom Jordan, Bristol (10:15) thanks for info @steve - no we didn't constrain the flow routing with the water hits (we just used them in a comparative sense). I think there are good opportunities still to develop a `probabilistic GL flow routing scheme' that combines formally combines, bed roughness, bed reflectivity, information from the surface,etc
Mike Prior-Jones, Cardiff Uni (author) (10:15) @Mark about 2000 euro per unit, plus my time
Ugo Nanni - U. Grenoble Alpes (author) (10:15) @Mike, is there a way to estimate the size of the conduit in which the Egg is travelling ? a measure of the water width or of the geometry around the sensor ? As you have the height you can estimate the water column but can you distinguish between a smalle pressurized channel and a large one at atmospheric pressure ?
Mike Prior-Jones, Cardiff Uni (author) (10:15) @Adam not sure - but fresh water will attenuate more than both ice and air
Mike Prior-Jones, Cardiff Uni (author) (10:16) @Juan Pedro - no, we expect to lose them.
Emma Pearce, Leeds (10:16) @mike how long is the battery life on the eggs?
Mike Prior-Jones, Cardiff Uni (author) (10:16) @Rob thanks! we can't yet track them, but I have a plan to do that in the future.
Adam Booth, Leeds (CONVENOR) (10:16) Thanks for the active discussion everyone! I'm going to give my fingers a rest, and pass the next sequence of abstracts to my co-convenor @Bryn Hubbard.
Mike Prior-Jones, Cardiff Uni (author) (10:17) @Andreas - we will definitely get some loss in transmission as it moves around, but we can deploy multiple receivers downstream to help mitigate that.
Liz Bagshaw, Cardiff (author) (10:17) @Adam: crevasses will impact the transmission to some extent, but given we're trying for 2.5 km, the impact of the crevasse should be negligible on overall transmission performance
Bryn Hubbard Aberystwyth U. (Convener) (10:17)
Bryn Hubbard here now to chair the next set of five presentations (D2312 – D2316). I think we have two Emmas presenting, so it may be best to use something like '@Emma L' and '@Emma S' for questions.

Mike Prior-Jones, Cardiff Uni (author) (10:17) @Ugo - I'm not sure - @Liz, can you shed some light on this?

Bryn Hubbard Aberystwyth U. (Convener) (10:17)
First up, Emma Lewington; the floor is yours Emma (L):

Roland Warner University of Tasmania (10:17) @Mike, as they are not buoyant, did you consider some sort of drogue to entrain it in flow rather than it setting in a pot-hole? Could that give scope for a bigger antenna?

Emma Lewington, Sheffield (author) (10:18)
Thank you very much. Morning all! I'm presenting some recent work today from my PhD.

Based on large-scale mapping across Keewatin, northern Canada, we suggest that geomorphic signatures recognised in high resolution digital elevation data offer the potential to gain new insights into the extent and nature of subglacial drainage.

Here, we propose a model for the formation of meltwater corridors, suggesting that they are the composite signature of repeated interactions between channels and their surrounding distributed drainage system, driven by over-pressurisation of the channel.

Our findings offer the potential to provide new insights into the relative coverage of different drainage forms across the ice sheet bed and provides a mechanism to access and mobilise sediment beyond the channel extent.

Olaf Eisen, AWI (CR PG) (10:18) @Mike/Liz: field trials in Greenland 2020 completely canceled or alternative plans for EGRIP?

Mike Prior-Jones, Cardiff Uni (author) (10:18) @Emma P: depends how you configure the sampling rate. Present design can do a measurement every two hours for a year, or a measurement per second for 6 hours. Revised design later this year should do hourly data for two years.

Steven Franke, AWI (author) (10:18) @Tom: I was referring to the 'water hits' but I formulated it wrong :) Sounds like a great idea. Is there more information regarding this?

Liz Bagshaw, Cardiff (author) (10:18) @Ugo: I don't think this would be possible. We will just know the pressure, temperature and solute concentration, and potentially the speed of the egg in transit. From this, you could make a guess on the size of the conduit (particularly by using the solute content), but I wouldn't want to rely on it.

Bryn Hubbard Aberystwyth U. (Convener) (10:18) Thanks @Emma L; questions?

Mike Prior-Jones, Cardiff Uni (author) (10:19) @Roland - the spherical shape was really about making sure it exited the bottom of the borehole and didn't get hung up anywhere.

Mike Prior-Jones, Cardiff Uni (author) (10:19) @Olaf: totally cancelled so far unless things change radically.

Liz Bagshaw, Cardiff (author) (10:20) @Olaf: we're still on lockdown, so it looks very unlikely that we'll get any testing in this year. Currently begging our funders and universities for contract extensions etc.

Bryn Hubbard Aberystwyth U. (Convener) (10:20)
@Emma L; very neat and a lot of work there, thank you. Do you have any ideas on whether the different esker-related landforms exist in certain spatial domains, possibly informing on different mechanisms of formation?

Rebecca Schlegel Swansea (author) (10:20) @Emma L. what time frame are we talking about in your models?

Ugo Nanni - U. Grenoble Alpes (author) (10:21) @Liz @Mike, thanks. Do you think an "echo-sounding" approach would work to estimate the geometry around the sensor. I might say something that is totally impossible.
Jade Bowling, Lancaster (PhD Student) (10:21)
sorry huge delay in these responses!

@Louis The 50+ lakes we detected in our 2019 paper are predominantly from RES and these appear to be stable. Our new study aims to detect more active lakes/ collapse basins and explore these in more detail.

@Rob thanks, yes that's definitely a possibility and my current thought, planning to look at optical downstream to see if we can see runoff

Mark Johnson Gothenburg Author (10:21) @EmmaL Very nice presentation and a beautiful map! Are you suggesting that the hummocks are formed by a kind of lateral-to-the-esker erosion, by meltwater flowing into the center?
Nate Maier IGE (10:21) @Emma L. Very cool work. Any hypothesis about what controls the VPA width from your geomorphic obs
Liz Bagshaw, Cardiff (author) (10:22) @Ugo: do you mean for the egg to send and receive pings within the channel? Possible, but I think the power requirements would be too great. We're concentrating on very simple measurements for now, since there are so many things that can already go wrong!
Nate Maier IGE (10:22) @ Emma L. Very cool work. Any ideas about what controls the VPA width in your geomorphic observations?
Andreas Alexander UiO (10:22) @Liz @Mike @Ugo I think it would be possible to make some estimations based on velocities and pressures. We are at the moment using acceleration data to reconstruct channel geometry (not size, but flow path), works quite well.
Mike Prior-Jones, Cardiff Uni (author) (10:22) @ugo - I guess in theory we could put a little ultrasound transducer on Cryoegg in the future, but it might be tricky to get all-round coverage. It would definitely use a lot of battery power though!
Olaf Eisen, AWI (CR PG) (10:22)
@Emma_L: on top to @Rebecca Schlegel Swansea (author) (11:20) @Emma L. what time frame are we talking about in your models?
Would you expect a difference between e.g. daily, seasonally or annual variations?
Ben Davison (Univ. St Andrews) (10:23) @Emma L: this is really neat and brings to mind some the processes that Ugo quantified in his presentation and paper. No question, just think it's great when two independent approaches shed light on (presumably) the same processes.
Emma Lewington, Sheffield (author) (10:23) @Bryn Thanks for your question, the esker 'splays' could potentially be forming subglacially (linked to deposition during the waning stages of 'flood' events) but they have also been suggested to form subaerially or even supraglacially at or close to the margin. We are not yet certain how to differentiate these based on geomorphology (without sedimentological filedwork).
Jade Bowling, Lancaster (PhD Student) (10:23) @Olaf, that's a great point and definitely something we should explore, thank you!
Kelly Hogan BAS (attendee) (10:23) @Emma L: It seems like the DEM preserves part (b) of your model, can you distinguish ebtween the different phases in the miorphology? Or the sediments maybe?
Liz Bagshaw, Cardiff (author) (10:23) @Ugo: there have been some similar experiments in karst systems, but they rely on getting the sensor back at the end

Bryn Hubbard Aberystwyth U. (Convener) (10:23) Lots of Q.s for @Emma L there; I'm hoping we can catch up on answers later. Time to move on now though...
Bryn Hubbard Aberystwyth U. (Convener) (10:24)
Great, thanks. Emma Smith next; over to you Emma (S):

Emma Smith - AWI (author) (10:24)
Hello all, "Emma S" here! In April 2019 we acquired seismic reflection profiles, using a **vibroseis source,** at two sites on **Kongsvegen, Svalbard**, to study the **internal and sub-glacial conditions** at the onset of a surge phase.

Site 1 (*little/no change in ice surface velocity*) - ice underlain by **uniform sediment package** ~ 60 m thick.

Site 2 (*highest increase in ice surface velocity*) - **cross-cutting layers** below bed, reflections in the 100 m above the bed indicate there could be shearing or sediment entrainment. **Internal ice reflection** at around 150 m depth could indicate ice fabric or temperature transition.

Lots more information in this data set still to look at! A short video of the vibroseis source in action: https://www.youtube.com/watch?v=kCwVIrL3a6Q&feature=youtu.be

Emma Pearce, Leeds (10:24)
@Emma S Great poster and really nice data! At what sort of distances are you able to image with Elvis? How far away can your shot be from your receivers before the signal is too weak?

Adam Booth, Leeds (CONVENOR) (10:25) Hi @Emma, nice one! Love an ELViS survey :) I handled some GPR data from Kongsvegen which showed loads of wierd englacial debris strucutres. Is your velocity control good enough to see any base-ice seismic velocity contrasts?
Bryn Hubbard Aberystwyth U. (Convener) (10:25) Take some time to take that in, but floor is open to questions (ideally to @Emma S in the first instance - we can always catch up wht others later) when peeps are ready...
Tom Jordan, Bristol (10:25)
@ steve – getting back to you again - there are few examples where radar-sounding reflectivity/topographic has been used to constrain -flow routing in a probabilistic way - Dusty Schroeder's Thwaites papers spring to mind here.

Louis Couston BAS (author) (10:25) thanks @Jade. do you have an estimate for the range of water depth of these lakes? Do you expect fundamental differences (e.g. typical salt concentration) between stable lakes in Greenland vs Antarctica?
Emma Smith - AWI (author) (10:26) @Emma P - on Kongvegen we were getting strong returns with a P-wave source from over 500 m of ice (warm and cold layers we think!). Offsets from source to receiver were up to around 350 m - so more than this. I know @Olaf and @Anja tested a similar source in Antarctica in 1000s m of ice - maybe they can comment.
Steven Franke, AWI (author) (10:26) @Tom: I'll have a look, thanks!
Emma Lewington, Sheffield (author) (10:26) @Rebecca and @Olaf Thanks for your questions, we expect that the geomorphic work is done with repeated pressure fluctuations (of varying maginitude from daily to seasonal events such as lake drainages) over 10s - 100s of years within the ablation zone with the esker forming later, close to the ice sheet margin. We

suggest that it is more to do with the size of the pressure fluctuation than the actual amount of water (i.e. a smaller input may cause a larger pressure fluctuatoin in the early or late melt season when the system is less channelised/ shutting down). We cannot know for sure however how many 'events' each feature repsents. I hope this answers your questions.

Bryn Hubbard Aberystwyth U. (Convener) (10:27)
@Emma S; many thanks Emma. In terms of the interpretation of the polarity change, do you believe the rest of the bed here is frozen or might there be some other contrast?

Bartosz Kurjanski (10:27) @Emma Smith: a technichal question. How many people and how long does it thake to deploy and collect e.g.1 km of data using ELVIS ;)?
Emma Pearce, Leeds (10:27) @Emma S, great! thanks! Another one.. in your data to you see any internal reflections in the ice, or does the bed reflection dominate the data?
Mike Prior-Jones, Cardiff Uni (author) (10:27) @Emma S - what kind of power consumption do you need for your survey? Is there any scope to deploy the ELVIS and instruments autonomously in the future?
Olaf Eisen, AWI (CR PG) (10:27) @Emma P - Russel Gl., GrIS: ELVIS p-wave in crevassed ablation zone in summer bed at 600-800 m hardly visible. Dry and cold obviously better.
Emma Smith - AWI (author) (10:27) @Adam - in short! Yes, I think it could be, but we haven't looked at it yet. As this data is high fold we can do a fairly detailed velocity anlysis. We do see internal layers (some just above the bed at site 2) so a nexy step would be to look at the moveout velocity of these.
Bryn Hubbard Aberystwyth U. (Convener) (10:28) Thanks @Emma S. Time flies; let's move on...
Bryn Hubbard Aberystwyth U. (Convener) (10:28)
Robert Arthern now; all yours Rob:

Robert Arthern BAS [author] (10:28) We consider three approaches to characterising basal drag. The main findings from each of the three panels are … 1) Inverse methods with a model that can compute vertical shearing show that Thwaites Glacier should have very strong vertical shearing near the bed. 2) Spectral analysis of the offshore bathymetry and a model of form drag (c.f. Nye 1970, Schoof, 2002) shows that bumps similar to those found offshore could create enough form drag to explain the high shear stress and strong vertical shearing. 3) Seismic surveys combined with acoustic modelling of sediment provide evidence that Coulomb friction, not form drag, is controlling the fast-flowing, slippery-based tributaries of Pine Island Glacier. So, we may need different flow laws for different places (e.g. form drag laws for rough parts of Thwaites, but Coulomb sliding laws for smooth Pine Island tributaries, and perhaps smooth parts of Thwaites).
Olaf Eisen, AWI (CR PG) (10:29) @Emma P - Kohnen station, Antarctica: hard to quantify, as only internal layers in the firn visible (see paper R Schlegel, AoG) and no strong R, as ice thickness 3 km. We did not test yet on cold firn with ice thickness around 1000 m, unfortunately.
Ugo Nanni - U. Grenoble Alpes (author) (10:29) @Emma L, very nice study. It is quite amazing of the features are preserved, and the link between the hydraulically connected distributed drainage system and the channels is very interesting.
Bryn Hubbard Aberystwyth U. (Convener) (10:29) Digest - and questions when you're ready. (Super stuff Rob)...
Emma Smith - AWI (author) (10:29) @Bryn - I suspect at Site 2 the bed is not currently frozen, as there has been a mass build up and strong surface velocity increase in this area. I

don't have a firm idea at the moment about what the areas of differing polarity could be yet, but there is certainly a lot of information in these data to be extracted.
Tom Jordan, Bristol (10:30)
Thanks for that @ Rob Arthern! Possibly a naïve question here – is your approach to infer basal drag very sensitive to the ice rheology/flow-law? (e.g. assumed or derived power-law exponent)

Emma Lewington, Sheffield (author) (10:31) Hi @Mark thank you for your question, we suggest that the model has a number of ways of potentially creating the hummocks including erosional i.e. by the turbulent flow of meltwater during channel breaching events which are analogous to narrow sheet floods or potentially due to the expansion of cavities during high pressure episodes or due to the distributed system taking the form of braided canals or even depositional i.e. by creep into cavities eroded into the bed or up into the ice - we acknowledge that many ways of creating these hummocks have been suggested in teh literature so far and think that this model provides a potential mechanism for explaining many of this (at different stages in the model).
Connor Shiggins1 (Uni of Liverpool) (10:31) @Rob: cool stuff! Are you planning on applying different flow laws to the locations in which you have suggested?
Nanna B Karlsson, GEUS DK (10:31) @Rob I don't know if you caught Emma Liu's presentation on Wednesday? I wonder how your work relates to their description of the formation of internal shear bands (related to topography)?
Emma Smith - AWI (author) (10:31) @Bartosz - we were a team of two! We transported the kit from Ny Alesund onto the glacier with 2 snow mobiles and set it all up on site. For data collection: We spent about 1 day per line - set up, acquistion and packing down. We were doing shots every 5 m into 48 channels - so I can't say how long it would take for 1 km, as it would depend on the configuration - but we can chat more about this after if you like!
Bryn Hubbard Aberystwyth U. (Convener) (10:32)
@Rob; super ideas, thanks. To your knowledge, is there direct evidence of deformable or heavily-deformed basal ice at Thwaites?

Bartosz Kurjanski (10:33) @Emma Smith: Thanks! That gives me an idea. Amazing effort!
Ben Davison (Univ. St Andrews) (10:33) @Rob A, great presentation, thanks. Do you envisage a roughness-dependent flow law then? if so, over what spatial scale should we be looking at basal roughness?
Emma Smith - AWI (author) (10:33) @Emma P - we saw internal ice reflections at 150 m depth and in the 100 m above the bed at Site 2 (purple arrows on display), it required a bit of playing with amplitude scaling, but the signals are there and could be seen on the shot records as well (fun for on site intial data excitement!)
Helen Ockenden, Edinburgh (10:33) @Rob Arthern How similar do you expect the offshore bathymetry to be to the subglacial topography?
Robert Arthern BAS [author] (10:34)
@Tom I think non-linear rheology will be important. It is included In the large scale model (Glen Law). For the form drag stuff this probably only gives order of magnitude results. More to do.

Emma Lewington, Sheffield (author) (10:34) @Nate thank you for your question, this is something we would really like to know more about and something which would be really useful, however, as we think that some / all of the corridors are the result of repeated pressure fluctuations, we cannot isolate the impact of a single event - it may be that the central channel is taking a slightly differnt pathway each melt season and therefore the whole system would

shift laterally and the signature would therefore reflect the merging of multiple signatures (as has been proposed for the formation of tunnel valleys). This may be why we do not see any consistent trends in width when we look acorss the whole area. I hope this answers your question.

Emma Smith - AWI (author) (10:35) @Mike - we used one large truck battery that we charged at the end of each day, we never ran it completely empty, so it lasts for at least 10 hours of fairly heavy use. No, no plans for remote deployment... could be an idea for changing systems though! Although you would only get one "shot" location repetedly, which isn't so helpful for imaging.

Bryn Hubbard Aberystwyth U. (Convener) (10:36)
Thanks all - so active this session... Next up is Basile De Fleurian. Are you here Basile? If so, over to you:

Basile de Fleurian UiB (10:36) I am afraid that home office has driven a nail in my productivity so nothing for me this year. It is great that others still manage to make that a lively session.

Tom Jordan, Bristol (10:36) Thanks @ Rob !

Robert Arthern BAS [author] (10:36) @Bryn Thwaites MELT project (led by Keith Nicholls and David Holland) drilled, but very close to the grounding line. Will be interesting to explore those data.

Bryn Hubbard Aberystwyth U. (Convener) (10:36) OK thanks Basile - we can all follow your Abstract - very interesting.

Bryn Hubbard Aberystwyth U. (Convener) (10:37)
Finally, Nico De Wald. @Nico, please go ahead:

Nico Dewald, UoSheffield (Author) (10:37) Hi everyone, I'm Nico, a PhD student at the University of Sheffield. We use high-resolution ($\leq$ 2m) digital elevation models to map geomorphological expressions of subglacial meltwater flow across Scandinavia. Because this is a very large area with a wealth of landforms and too many details to capture within a reasonable period, we adapt our way of mapping and combine different expressions of subglacial meltwater flow into what we call a subglacial meltwater route. Subglacial meltwater routes aim to illustrate routes of active subglacial drainage during the deglaciation of the Scandinavian Ice Sheet. Our preliminary dataset reveals interconnected and more detailed network structures than previously seen from single-landform maps. Our final map will cover Norway, Sweden, Finland, and eastern parts of Russia and will be used as a basis for further studies about the long-term effects of subglacial meltwater drainage on ice sheet dynamics.

Matt Trevers, Uni of Bristol (10:37) @ Rob: Hi Rob, thanks for the presentation. From a modelling perspective, do you think something along the lines of the sliding law presented by Tsai et al (2015) which is Coulomb-limited by a minimum function might be ideal for modelling Thwaites? Thanks

Bryn Hubbard Aberystwyth U. (Convener) (10:37) Thanks Nico - another substantial contribution. Qestions:

Rebecca Schlegel Swansea (author) (10:38)
@Nico, the eskers and hummocks you show, how far (temporal) apart are they created?

Ben Boyes, UoB (10:38)
@Nico, Interesting work! I wondered, are you going to be extending your study area to the entire FIS bed (i.e. including northern Europe), or are you focussing on the area covered by the ArcticDEM?

Also, how are you conducting the mapping? Is it a manual process, or are you using some form of automated mapping?

Olaf Eisen, AWI (CR PG) (10:38) @Emma S. / @Mike "not so helpful imaging" - it is useful, see pothole drainage in 90s observed by Matt Nolan on Black Rapids Gl.. ELVIS would be useful for observing subglacial system changes over course of melt season, as always the same source signal

Emma Lewington, Sheffield (author) (10:39) @Ben Thanks, I was very interested to see @Ugo's presentation, its great to see the methods being used to assess this process in contemporary settings and hopefully looking at the different approaches together can help enhance our overall undersatnding!

Robert Arthern BAS [author] (10:40) @Ben There may be two end members. One dependent on roughness. One depending on sediment properties. Real world may be some combination. Seems like the power spectrum falls off slowly (inverse square of frequency), so the shorter scales are important.

Emma Smith - AWI (author) (10:41) @Olaf @Mike - yep good point! I wanted to say that we couldn't build up a stacked image as I show on my slides, but there is still a lot of useful information in a single repeatable shot.

Adam Booth, Leeds (CONVENOR) (10:42) Thanks @Bryn for overseeing that sub-session. I would echo @Bryn's comments that this session is amazingly active - thanks everyone! I would say that you can do a 'Select All', then copy and paste, in the above window and capture the conversation for posterity - that way, speakers can have a record of the discussions that they had amongst a whirlwind of commentary!

Mike Prior-Jones, Cardiff Uni (author) (10:42) @Emma/Olaf - happy to talk about remote power systems for future work if that's helpful.

Adam Booth, Leeds (CONVENOR) (10:42) The baton now passes to @Rob Bingham to lead us through the next abstracts...

Robert Arthern BAS [author] (10:42) @Helen We looked at power spectra for both onshore and offshore. They seem similar. See Kelly Hogan's paper in TCD for more details https://www.the-cryosphere-discuss.net/tc-2020-25/

RobBingham UEdinburgh (covenor) (10:43)
Hi folks, delighted to be here now to convene the next set of abstracts D2317-D2322. Before we get going, I'd just like to allow a minute to pass to allow everyone to catch their breath, and for the stream of questions from previous talks to slow. So hold your fire please…!

Emma Smith - AWI (author) (10:43) @Mike - I am sure it would be for this and/or other systems - thanks!

RobBingham UEdinburgh (covenor) (10:44)
OK, we're now ready to go and I'd like to invite @Jacob Woodard to introduce D2317. @Jacob: the floor is yours…

James Kirkham, BAS (Author) (10:44)
@ Emma Lewington. Really nice work. Can you give some insight into the timings of erosional landform production (tunnel valleys) compared to depositional (eskers)? Do you think the meltwater tracks are formed first by a more erosive subglacial hydrological system (or maybe persist from previous glaciations?) and then depositional landforms are deposited in these tracks later, or does erosion and deposition within these meltwater tracks occur concurrently?

Will Harcourt, St Andrews (PhD Student) (10:45) @Emma @Mike Remote power systems was a key topic of discussion for Svalbard and Arctic based research - lots of problems to be resolved!
Nico Dewald, UoSheffield (Author) (10:45) @Rebecca that's a really good question and I'm afraid I can't give you a number right now. Eskers are usually on top of other landforms which means they were created at a later stage but it's hard to say how much time passed in between.
RobBingham UEdinburgh (covenor) (10:46) Nothing heard from @Jacob - is anyone here from D2317 to present anything?
RobBingham UEdinburgh (covenor) (10:46) While I wait, I will point out that this is a very nice poster, so please take a look.
RobBingham UEdinburgh (covenor) (10:47) OK folks. Next up is abstract D2318, Christian Vincent. I didn't see a presentation uploaded for this; @Christian are you there?
luke zoet (WISC) (10:47) @rob I think @jacob got mixed up with the change away from zoom and so is not here
Robert Arthern BAS [author] (10:48) @Matt There is lots of evedence for that style of law, both for hard beds (cavitation) and for sediment (see Luke's great experiments in this session).
RobBingham UEdinburgh (covenor) (10:48) OK folks, think my previous convenors have cursed me...
RobBingham UEdinburgh (covenor) (10:48)
OK… unfortunately both abstracts D2319 and D2320 have been withdrawn, so we now move on to D2321 and @Rebecca Schlegel. @Rebecca, please go ahead.

Rebecca Schlegel Swansea (author) (10:48)
Hi everyone,

As part of my PhD, we have collected a 3D radio-echo sounding dataset on the Rutford Ice Stream. This dataset then has been 3D migrated and attribute analysis has been done for the bed reflection. Three different 3D grids were acquired, focussing on different areas, with the overall aim to investigate the basal properties (what kind of porosity? What kind of sediment? Water content?) but also to get a high resolution image of the landforms we find under the Rutford. Our preliminary results indicate that we might have a mosaic of very compressed sediment or bedrock as well as very soft, water saturated sediment present at the bed. By understanding the bed properties around the landforms, we hope to better understand their formation as well as the dynamics present at the Rutford.

RobBingham UEdinburgh (covenor) (10:49)
@Rebecca a.k.a. Donald Duck (see poster if you don't follow this). Very nice set of slides and wonderful data thanks. The floor is open:

Robert Arthern BAS [author] (10:50) @Matt The GHOST project in the International Thwaites Glacier Collaboration, led by Sridhar Anandakrishnan and Andy Smith, will be taking all of these approaches much further, with many US and UK partners, plus AWI.
Emma Lewington, Sheffield (author) (10:50) @James Thank you very much for your question. We expect that the tunnel valleys / meltwater corridors were formed within the ablation zone over 10s - 100s years where fluctuating surface meltwater inputs were concentrated and the cumulative subglacial draiange was sufficient to access and mobilise the sediment. The eskers were then formed later on at / near to the margin. I hope this answers your question.

Nico Dewald, UoSheffield (Author) (10:50) Thanks **@Ben B.**! I'm using national DEMs so I can map beyond the margins of the ArcticDEM. Our primary aim is to cover the Fennoscandian Peninsula and the eastern part of Russia although I'll plan to take a look at the southern margin as well if we get access to the data. Mapping is done manually, although there is some work done to automate some of the mapping (e.g. hummock corridors, see Lewington et al, 2019).
Emma Smith - AWI (author) (10:51) @Rebecca - has this new survey changed or refined the location or interpreation of the long held soft/hard bed transition zone under Rutford?
E. Magnússon UI (author) (10:51)
Hello everyoneStudy subject: Subglacial lake maintained by ~1 GW geothermal area causing large destructive jökulhlaups

Motivation: Knowing the size of potential jökulhlaup before they occur

Tool: Low frequency radar

Method: Repeating annually network of radar profiles

Main content of slides: Aimed to convince you that by comparing repeated profiles we can discriminate traced refection into reflections from solid glacier bed and reflections from lake roof from changes in reflection elevation. Based on this we map bedrock topography as well as lake margin, lake depth and obtain water volume annually in 2014-2019.

Proof of concept: Fairly agreement good agreement with jökulhlaup volumes obtained with radar profiling (in 2015 and 2018) and volumes obtained from surface lowering during jökulhlaup few months after survey.

Bonus: New insight into the shape development of a subglacial lake formed by strong geothermal activity

E. Magnússon UI (author) (10:52) sorry mistake
E. Magnússon UI (author) (10:52) back to this later
Adam Booth, Leeds (CONVENOR) (10:52) Haha, I guess we'll return to this in due course! :D
Emma Lewington, Sheffield (author) (10:53) @Rebecca I really enjoyed your presentation! I saw that you said this was the same area as previous work by Smith et al., 2007, I was just wondering if you are you able to tell if there have been any changes at the bed over time? It is really cool that you have repeat surveys for the same area!
Olaf Eisen, AWI (CR PG) (10:53) @Rebecca: Envelope (pseudo-reflectivity) - is your signal robust (reflectivity anomaly on the ridge) as you did consider only thickness variation for correction? How about geometric effects (always diffcult to get from amplitude to reflector properties).
Rebecca Schlegel Swansea (author) (10:54)
@Emma S. a little, as the new survey covers a way smaller area, only that small area will be refined, but with the 3D dataset we got a really good image of what the topography looks like in the transition between the different types of bed, and therefore also the landforms. But yes I would say my interpretation of the transition zone differs a bit from what was assumed so far, but not too much

Emma Pearce, Leeds (10:55) @rebecca do you assume thee differences in interpretation are from changes in the subsurface over time, or changes in the way you have interpreted the data?
Emma Smith - AWI (author) (10:55) @Rebecca - thanks! It looks like the transition is more complex than just hard-to-soft from your analysis.
Rebecca Schlegel Swansea (author) (10:56)
@Emma L. from repeated seismics and radio-echo sounding, we know that there are some parts of the bed that do show changes (mainly local erosion, but also a deposition of material was observed). From seismics acoustic impedance a change in bed properties has also been observed over several years.

RobBingham UEdinburgh (covenor) (10:57)
Thanks @Rebecca and all questioners on D2321. In the interests of time we must move on, but there may be some time at the end of the session to come back to various questions. Next up is abstract D2322, I think this is going to be presented by Nanna Karlsson (?)

Nanna B Karlsson, GEUS DK (10:57) I am happy to take questions... and I think Ian Hewitt is also here so you can direct model-related questions to him :)
RobBingham UEdinburgh (covenor) (10:57) OK, great. Questions for Nanna and Ian please!
Harold Lovell (Portsmouth): co-convener (10:58) Hi @Nanna: Hagen Brae is one of several ice sheet outlet glaciers that are known to surge in Greenland, primarily located in the north. Why don't we see more surge behaviour for outlet glaciers/ice streams elsewhere in Greenland (e.g. West Greenland), or even in Antarctica?
Rebecca Schlegel Swansea (author) (10:59)
@Olaf, what kind of geometric effects are you referring to? I did some cross-plots of slopes and azimuth vs. the reflectivity to see if there is a clear visible relation, but haven't seen anything, not surprisingly as the bed is pretty flat.

Olaf Eisen, AWI (CR PG) (10:59) @Nanna/@Ian: How much does this go beyond the great unification theory of glacier surges by Doug and others a couple of years ago? Difficult to tell from an abstract only ...
Rebecca Schlegel Swansea (author) (11:00) @Emma S. agree, it seems to be more complex, hopefully more work on the data will reveal more information on that
Nanna B Karlsson, GEUS DK (11:00) @Harold In West Greenland, there is too much water essentially. To have a surge the glacier needs to be able to build up but the W Greenland glaciers can't (I would also refer to the paper by Sevestre and Benn about accumulation/temperature regimes that allow for surging)
RobBingham UEdinburgh (covenor) (11:00)
Many thanks to all presenters (and question fielders) in this part of the session. It's now my pleasure to pass on convening duties to Harold Lovell for the final set of presentations this morning. Over to you @Harold.

Harold Lovell (Portsmouth): co-convener (11:01) Thanks Rob. Next up we have @Lucas Zoet. Over to you @Lucas
luke zoet (WISC) (11:01)
Using a laboratory device designed to simulate glacier slip we estimate the drag response from temperate ice slipping over a deformable till bed.

1) We find that deformation is localize to a narrow zone near the ice-bed interface.

2) We also find that at low sliding speeds the ice slides over and around clasts at the ice bed interface, which is largely rigid, and form drag dominates. At a specific transition speed the stress exerted by the ice on the bed causes clasts located at the ice-bed interface to begin to plow, above which speed the bed behaves like a coulomb material.

We propose a specific way to estimate the transition speed based on plowing mechanics. We also propose a generalized slip law that approximates both the rate strengthening response at slow speeds and the coulomb response at higher speeds that depends on the transition speed estimate.

Harold Lovell (Portsmouth): co-convener (11:01) Great. Any questions for @Lucas?
Harold Lovell (Portsmouth): co-convener (11:02) Sorry... @Luke
Robert Arthern BAS [author] (11:02) @Nanna Yes, the possible link to Emma Liu's stuff is really interesting. Perhaps shear localisation limits which roughness features are important. Her length scales seemed about right. She uses no-slip at the bed I think, but the shear band might be so weak it approximates no slip. More to investigate.
Nanna B Karlsson, GEUS DK (11:02) @Olaf The study is an attempt to resolve how surges can initiate in the ablation zones. Previous studies have mainly focused on surges triggered in the accumulation zones. It ties in with the enthalpy surge paper that Doug Benn and others published last year... so yes, towards a grand unification of surge theory
Emma Lewington, Sheffield (author) (11:02) @Kelly appologies for missing your question earlier, I have just seen it... unfortunately we do not have access to any sediments, however, the morphology may be able to give insights into the different phases, for example we may expect greater relief (i.e. more developed tunnel valleys) in areas which experienced the greater pressure fluctuations (i.e. b3) - however, as we expect these to be composite signatures with repeated events, we cannot say for certain whether a feature was necessarily caused by a single large event or repeated lower magnitude events.
Ugo Nanni - U. Grenoble Alpes (author) (11:02)
@Luke. Around 8min on your presentation you show the Shear stress/strength vs Sliding speed with and without clasts. Both show a plateau at the Coulomb failure point. Do you expect this plateau to be followed by a drop of the Shear stress/strength as in a double-dragged sliding law (e.g. as in your 2015 paper) ?

Liz Bagshaw, Cardiff (author) (11:02) @luke I loved seeing the description of the experiment on your video - it made the paper come to life. Basic question from a non-modeller: does this mean we can't figure out which law applies unless we know the size of the clasts?
Rebecca Schlegel Swansea (author) (11:03)
@luke, how reasonable is it to use a 150kPa of effective stress? And do you have pore pressure sensors in your set up?

Emma Smith - AWI (author) (11:04) @Luke - this isn't my area of experise...so possible I have missed something, but do your results suggest that above a transition speed all beds behaven like a coulomb material?
luke zoet (WISC) (11:04)

@Ugo, probably not. I think for a deformable bed, unless it's somehow supporting cavities it will stay coulomb. That's not to say that transients couldn't be rate-weakening thus still producing seismicity

Sofia Kufner, BAS (attendee) (11:04) @luke: thanks for this great presentation. Do you think your setup would produce acoustic emisssions (=basal icequakes) at any point?
Harold Lovell (Portsmouth): co-convener (11:06) OK it's time to move on. Next up, after a teaser previously, we have @Eyjolfur et al. Over to you @Eyjolfur
E. Magnússon UI (author) (11:06)
Hello everyone and sorry for the previous premature posting!

Study subject: Subglacial lake maintained by ~1 GW geothermal area causing large destructive jökulhlaups

Motivation: To know the size of potential jökulhlaup before they occur

Tool: Low frequency radar

Method: Repeating annually network of radar profiles

Main content of slides: Aimed to convince you that by comparing repeated profiles we can discriminate traced refection into reflections from solid glacier bed and reflections from lake roof from changes in reflection elevation. Based on this we map bedrock topography as well as lake margin, lake depth and obtain water volume annually in 2014-2019.

Proof of concept: Fairly agreement good agreement with jökulhlaup volumes obtained with radar profiling (in 2015 and 2018) and volumes obtained from surface lowering during jökulhlaup few months after survey.

Bonus: New insight into the shape development of a subglacial lake formed by strong geothermal activity

luke zoet (WISC) (11:06)
@Liz No I think it could be determined and applied in other ways. For example with geophysics or possibly inversions like rob does. It just means that the transition is depended on actually measurable properties of the till (and effective stress). If you knew those it would be directly computable.

Harold Lovell (Portsmouth): co-convener (11:06) Thanks! Any questions for @Eyjolfur?
Liz Bagshaw, Cardiff (author) (11:07) @luke thanks
Mark Johnson Gothenburg Author (11:08) @Eyjolfur I did not see it directly in your paper, but is there a correlation between lake volume and jokulllhaups?
Harold Lovell (Portsmouth): co-convener (11:09) @Eyjolfur: And a follow up to Mark's Q - what might account for the underestimation of lake volume versus measured jökulhlaup volume? Time of data collection versus drainage time?
luke zoet (WISC) (11:09)
@ Rebecca. 150 kPa is high for an Antarctic subglacial condition. It doesn't really matter though because the entire thing is related as a function of friction and so normalized by the effective stress. The entire response could be mapped out to any effective stress, you just would have to know what it was. At lower effective stress the system would behave more

like a coulomb material over a wider range (i.e. lower) velocities. Yes we have water pressure sensors in the device so we can monitor this throughout the experiment.

E. Magnússon UI (author) (11:11) @Mark Slide 21 in my pres shows comaprison between jökullaup volume obtained with radar profiling few months before jökulhlaup and jökulhlaup volume obtained from surface lowering during jökulhaup
Harold Lovell (Portsmouth): co-convener (11:12) Thanks @Eyjolfur**.**Moving on… time for the next presentation: Andrea Walpersdorf et al. Is anyone available to talk about D2326? If not we'll move swiftly on…
Louis Couston BAS (author) (11:12) @Eyjolfur: what is the study area associated with the 1GW flux?
Olaf Eisen, AWI (CR PG) (11:12)
@**Eyjolfur**: Great data! Did you consider to complement with active seismics (at least at some spots), as these data would give you a better handle on th lake bed and the roof? (Thinking about hammer or stationary ELVIS from @Emma_S display).

Indications of bed topo changes caused by Jökuhlaup?

luke zoet (WISC) (11:12)
@emma s, above the transition speeds deformable beds behave as Coulomb material. Our other work shows that rigid beds can have a rate weakening component from cavitation if the bed geometry is right

Louis Couston BAS (author) (11:12) @Eyjolfur: I meant what is the surface area?
Emma Smith - AWI (author) (11:12) @Luke - thanks, that's clearer now.
Harold Lovell (Portsmouth): co-convener (11:13) I think we'll move on… which brings us finally to @Mark Johnson et al. Over to you @Mark
E. Magnússon UI (author) (11:13) @ Harold. Time of data collecation, radar profiling undersampling of the lake (in 2015 in particular), errors in bed DEM at the cetner of the lake
luke zoet (WISC) (11:14) @Sofia Yes I do think it would produce acoustic emissions. I've built a new device here in a way that it is possible to outfit it with PZT to detect acoustic emissions if the right project comes along
Mark Johnson Gothenburg Author (11:14) I will present my sentences in a few bite-sized chunks!
Mark Johnson Gothenburg Author (11:14)
Mäkinen et al (2017) and Peterson et al (2017) reported the discovery of a unique triangle-shaped hummock in Finland and Sweden. New LiDAR-based DEMs made these apparent for the first time. We call these MURTOOS (Ojala et al (2019).

Though these have been unsuspectingly mapped in preceding decades under the garbage-can term of 'hummocky topography' or 'dead-ice moraine', it is clear these are DISTINCT forms and that they are FORMED SUBGLACIALLY:

Murtoos are superposed with eskers, De Geer moraines and glacial lineations in places. Their distinct V front is strongly pointed in the local ice-flow direction.

Murtoos are not uncommonly associated with ribbed moraine where they appear to be slightly younger, by cross-cutting relationships.

They also can be found in corridors associated with eskers and meltwater/hummock corridors (like those Emma Lewington described earlier today).

Mark Johnson Gothenburg Author (11:14)
Numerous machine-dug trenches reveal murtoos to be composed of heterogeneous diamicton stratified with sorted sediment, often slightly deformed.

Mark Johnson Gothenburg Author (11:15)
Their geographic distribution in Scandinavia shows that they are most common in places where ICE-MARGIN RETREAT WAS FAST (100-200+ m/yr), during the Bölling-Alleröd and in the early Holocene following the Younger Dryas. They are associated with warming climate. We think murtoos formed near to, but at least 10's of kilometers, behind the ice margin.

Mark Johnson Gothenburg Author (11:15)
Their GENESIS is unclear. But our working hypothesis includes SUBGLACIAL DEFORMATION with an input of SUPRAGLACIAL MELTWATER: the forms are made by drag of till, and shaped at the margins by meltwater. Numerous surface boulders suggest a lag. We also hypothesize that murtoos are made where the bed is transitioning from a DISTRIBUTED flow system to a more efficient CHANNEL-flow system (as indicated by the eskers).

Mark Johnson Gothenburg Author (11:15)
We think they should be in Canada and are awaiting their first observation there. Thank you.

Harold Lovell (Portsmouth): co-convener (11:16) Thanks @Mark. Any questions?
Harold Lovell (Portsmouth): co-convener (11:17) @Emma L: Any sign of these in your work? Are your DEMs high enough resolution?
E. Magnússon UI (author) (11:17) @ Olaf. Thats a good idea, which I had not conscidered. We have however also 2 borehole surveys near the lake center (see slide 18), which helps us constraning the bed where we lack radar observations of it.
Harold Lovell (Portsmouth): co-convener (11:18) And perhaps one for @Mark too: where would you target if you were looking for these elsewhere?
Emma Lewington, Sheffield (author) (11:19) @Harold I have been looking! I've largely been using 10 m arctic dem for my large-scale mapping (as this was what was available when I started) which is great but you cant see that level of detail for individual hummocks as well as you can in the amazing 2 m swedish data! Now that I am moving on to more detailed observations with the newer releases, I am keeping my eyes open.
Mark Johnson Gothenburg Author (11:20) @Harold In Scandinavia, the murtoos are on the shield, where the till is thin. This is what makes us think of Canada, of course. I wouod not expect to find them where subglaciall sediment is thick (10's of meters)
Nico Dewald, UoSheffield (Author) (11:21) @Mark, these features are very interesting! One thought that came to mind during my mapping campaign: Could topography/slope play a role in their distribution as well? Maybe on a more local scale? Have you looked into that perhaps?
Harold Lovell (Portsmouth): co-convener (11:21) Thanks @Mark and @Emma L. Back to Adam...
Adam Booth, Leeds (CONVENOR) (11:21)
Thanks everyone for your contributions today – CR5.9 had 124 users at its peak, and I think the activity in this session has been awesome!

Adam Booth, Leeds (CONVENOR) (11:21)
I'd also thank the co-convenors, including Christine Dow in absentia! I would also say – and this is without the EGU buying me a beer in advance – that I'm also really grateful to the EGU for trying this new format rather than abandoning the conference altogether. There are definitely elements of it that I think we should keep at future meetings; it has actually been much more successful that I was initially anticipating 😊

Adam Booth, Leeds (CONVENOR) (11:21)
We will set up something to facilitate the recording and dissemination of the invited contributions in due course – keep your eyes peeled!

E. Magnússon UI (author) (11:21) @ Louis. The ~1GW referrs to the area maintaining the surface cauldron, the exact area at the bed is not certain but the diameter of the cauldron is 3-4 km

Mark Johnson Gothenburg Author (11:22) Yes it does, @Nico. We mapped 'geomorphons' for alll of Sweden, and the murtoos occur primarily on relatively flat surfaces sloping in the same direction of the ice flow.'

Adam Booth, Leeds (CONVENOR) (11:22)
Obviously, that's the ebd of the formal proceedings. We will leave this session open for the remaining ~10 minutes and invite any extended discussion on any abstract. However, those extended discussions can also take place via a Slack channel that @Ugo Nanni has very generously set up. Please do sign up here - https://join.slack.com/t/subglacialenv-kiy8919/shared_invite/zt-ehsxtsyo-nHZot5wb9GrZMtmQsb5GAw - if you are interested, it could be a really good way to capture the energy of this session!

Adam Booth, Leeds (CONVENOR) (11:22)
With this, your convenors will now take a back seat, and let the discussions (and then the beers) flow! Great to chat to each and every one of you. Stay safe, and we'll see you soon.