IASC-CWG workshop summary report

"Workshop on observing and modelling meltwater retention processes in snow and firn on ice sheets and glaciers"

confronting "the problem that won't go away"

1-3 June 2016, Øster Voldgade 10, DK-1350 Copenhagen

Overview

Dr. Robert Fausto and Prof. Jason Box of the Glaciology and Climate department of the Geological Survey of Denmark and Greenland (GEUS) hosted an International Arctic Scientific Committee "Workshop on observing and modelling meltwater retention processes in snow and firn on ice sheets and glaciers", 1-3 June 2016, Øster Voldgade 10, DK-1350 Copenhagen. There were 50 registered participants. A Workshop Agenda including participants list is attached to this report.

Discussion framed how to approach a problem confronting this community for 40 years.

Scientific Highlights

We organized sessions by observations, modeling, synthesis and thus list the first three Scientific Highlights in response to the questions:what **observations** are we missing? lateral continuity of ice layers, unsaturated hydrological conductivity, and irreducible water content topped a list that also included grain growth. Also on this list is having geo-statistical information of retained meltwater, i.e. spacing of conduits, lenses, and layers in horizontal and vertical. Two retention regimes on the lower accumulation area of the GrIS were highlighted: blocked percolation in the West and firn aquifer in the Southeast. The transition between these two zones is still unmonitored.

1. Regarding **modeling**, how do we parameterize vertical transport in preferential paths? An idea is to assume perfectly efficient vertical transfer allowing water to exit one layer and reappear in entirety skipping some model layers below. Another was to redistribute the meltwater from the surface to the underlying layers by using "percolation curves". For alpine snowpack, advances have been made in modeling wetting front instability after a fine to coarse grain horizon. The preferential pathways enhanced by ice layers are still not being modeled. Simple model including meltwater availability, depth and horizontal density of the preferential pathway and refreezing rates should give a first estimate of how important the process is.
2. Regarding **synthesis**, we resolved it important to ranking of 'what is important', the outcome of which suggested that with the expected future warming, accurate treatment of meltwater retention in the upper accumulation area will be fundamental. Actionable ideas how to expand much more realistically on the seminal work of Pfeffer et al. (1991) include: repeat it with modern data and methods (topography, hypsometry, firn, depth, 2 models easy runoff model 2 obstacles to runoff model). Regarding heterogeneous percolation of meltwater, it was agreed that no

quantification of its extend neither of its importance for SMB processes was available. Simple model experiments (water availability vs. percolation rate vs. refreezing rate) were suggested to get an idea of the relevance heterogeneous percolation modelling in polar firn.

3. The group discussed: To what accuracy do we need to know retention? We can design simple questions to address the question. Several participants agreed that Greenland ice sheet SMB calculation did not need to include microscopic modeling of percolation blocking or heterogeneities and that only the overall effect should be accounted for.
4. To address the discussed question:"what constitutes a useful validation data set?", we developed a list of Key observables and methods to accomplish the observation.
5. Accurate surface observations are needed to get the atmospheric forcing parameters and computed melt correct. Multi-year cores and temperature records that cover as much of the percolation area (~15-20m) as possible are very useful.

Key observables (method)

1. snowfall accumulation rate versus time
2. snowfall density (coring, snow pits)
3. firn ice content (stratigraphy from coring, snow pits)
4. firn air content (density and stratigraphy from coring, snow pits)
5. liquid water content (TDR, upward looking GPR)
6. irreducible water content (only from laboratory experiment?)
7. hydraulic conductivity (tomography?)
8. snow grain size (NIR photography)
9. thermal evolution (thermistor strings in top 25 m)
10. compaction rate (continuous logging strain gauges, a.k.a coffee cans)
11. 3d snow/firn mapping (multiple coring, Meier snow guillotine, large scale tomography)
12. stratigraphy, i.e. discontinuities (NIR photography)

Key model challenges (method)

1. vertical water motion in snow and firn within one grid cell, i.e. inhomogeneous meltwater percolation (piping)
2. horizontal water motion in snow and firn between grid cells
3. formation and thickness of continuous 'impermeable' ice layers in firn
4. formation and magnitude/thickness of continuous perennial firn aquifers
5. formation of local discontinuities, grain growth and the influence on the hydraulic conductivity
6. Accounting for the different dominating processes depending on the scale

Recommendations

1. make no model intercomparison until adding something new in the model about heterogeneity that is testable.

2. In many applications and considering the high complexity of meltwater movement and refreeze in heterogeneous firn it seems worthwhile ‘don’t worry about the details’, i.e. add a physical based parameterization resolving heterogeneous meltwater percolation in firn on grid scales from 500m to 5km
3. Track energy convergence/divergence in the vertical
4. have models track ice layer development of impermeable layers
5. local heating from the arrival of water is a valuable tracer
6. model intercomparison driven by same observational dataset
7. validation using observations, not between models.
8. ways to image snowpack 3d include excavation or as yet unavailable larger scale (than mm) tomography
9. do the grain by grain modeling then rewrite it elegantly and efficient computationally
10. deeper thermistor strings
11. cite/investigate older work, e.g. Braithwaite (1994)

PROGRAM:
Workshop on observing and modeling meltwater retention processes in snow and firn on ice sheets and glaciers

Hosted by the Geological Survey of Denmark and Greenland (GEUS)

1-3 June 2016, Øster Voldgade 10, DK-1350 Copenhagen

Sponsorship: Danish Council for Independent Research (DFF)
and International Arctic Scientific Committee (IASC) co-sponsored

Practical items:

- **What will the workshop include:**
  - Icebreaker on Wednesday
  - Morning and afternoon coffee breaks.
  - Lunch Thursday and Friday.
  - Workshop dinner on Thursday (Please let me know, if you plan NOT to attend)
- **Poster session**: Thursday afternoon. Please use the prepared poster holders in the hallway
- **Discussion sessions:** discuss observations and model development of meltwater retention processes in snow and firn.
- **Please be on time for each session as the main entrance to GEUS will be locked most of the time during the workshop.**

Need help?:

- Robert work phone: Call +4591333838
- Robert private phone: Call or text +4525132694

Publication:
We plan a special issue on the workshop topic in Frontiers in Earth Sciences – Cryospheric sciences [link].

Oral presentations

Wednesday 1 June		**Title**
12.00-13.00	Registration	
Convener: Jason Box		
13.00-13.10	Introduction	
13.10-13.40	W. Tad Pfeffer	The little problem that won't go away: 50+ years of research on Greenland meltwater infiltration
13.40-14.10	Roger Braithwaite	Measurement and modelling of meltwater retention on ice sheets and glaciers

14.10-14.30	Carl E. Bøggild	Melt water in cold polar snow: a system of observational, understanding and modeling challenges
14.30-14.40	Dirk van As	Expert Survey
Break		
Convener: Dirk van As		
15.00-15.20	Richard Forster	Greenland firn aquifer investigations from remote sensing, geophysics, in situ measurements, and modeling
15.20-15.40	Mike MacFerrin	Compaction and firn cores from the Greenland ice sheet 2012-2016
15.40-16.00	Paul Vallelonga	Observations regarding the 2012 melt event in the Greenland accumulation zone
16.00-16.20	Peter Kuipers Munneke	Modelling elevation change of the Greenland Ice Sheet firn layer, 1960-2014
16.20-16.40	Discussion points for the next days	**Discussant: Jason Box**
16.40-18.30	**Ice Breaker**	**Sponsored by International Arctic Science Committee (IASC)**
Thursday 2 June		
Convener: Babis Charalampidis		
09.10-09.30	Jens Hesselbjerg Christensen	Sea ice – what does this has to do with the Greenland Ice Sheet SMB?
09.30-09.50	Konrad Steffen	Greenland Swiss Camp Climatology: 1990 - 2016
09.50-10.10	Horst Machguth	Successive and intense melt rapidly decreases Greenland meltwater retention in firn
10.10-10.30	Stef Lhermitte	Clouds enhance Greenland ice sheet meltwater runoff
Break		
11.00-12.20	Discussion	**Discussant: Koni Steffen**
Lunch		**Sponsored by International Arctic Science Committee (IASC)**
Convener: Baptiste Vandecrux		
13.30-13.50	Stefan Ligtenberg	Modelling 3-D liquid water flow in the Greenland firn aquifer
13.50-14.10	Sebastian Mernild	Surface mass balance and runoff modeling for Greenland Ice Sheet based on SnowModel
14.10-14.30	Peter Langen	Introducing percolation physics in the regional climate model HIRHAM5
14.30-14.50	Nander Wever	Recent advances in liquid water flow modelling in the physics based SNOWPACK model
Break		
15.20-16.30	Discussion	**Discussant: Michiel van den Broeke**
16.30-18.30	**Poster Session**	
19.00-23.00	**Workshop dinner**	Café G [link] **(Co-sponsored by IASC)**

Friday 3 June		
Convener: Xavier Fettweis		
09.10-09.30	Jan Leanerts	Firn air depletion and high melt in grounding zone of an East Antarctic ice shelf
09.30-09.50	Samantha Buzzard	The accumulation of surface meltwater on ice shelves
09.50-10.10	Christian Steger	Refreezing and liquid water storage on the Greenland ice sheet: a model comparison
10.10-10.30	Kristin Poinar	Model-based constraints on the depths and thermal influence of water-filled crevasses in western Greenland
Break		
Convener: Ruth Mottram		
11.00-11.20	Sergey Marchenko	Measuring and simulating snow/firn temperature evolution at Lomonosovfonna affected by preferential water flow
11.20-11.40	Samira Samimi	Meltwater Runoff and Storage Based on Dielectric Properties of the Supraglacial Snowpack on Haig Glacier, Canadian Rocky Mountains
11.40-12.00	Achim Heilig	Continuous determination of liquid water retention in seasonal snowpacks and application to perennial firn.
12.00-12.20	Björn Saß	Improvement of geodetic glacier mass balances with integrated firn elevation change modeling
Lunch		**Sponsored by International Arctic Science Committee (IASC)**
13.30-15.00	Discussion	**Discussant: W. Tad Pfeffer**

Poster presentations

	Posters:	**Title**
1	Patrick Alexander	The impact of meltwater on modeled Greenland Ice Sheet density profiles
2	Willem Jan van de Berg	On the densification of snow
3	Matthew Cooper	What can supraglacial rivers on the Greenland Ice Sheet teach us about seasonal meltwater retention in snow and firn?
4	Alexandra Gossart	The importance of wind on East Antarctic ice shelf stability
5	Juliana Costi	Surface meltwater production, retention and runoff trends on the Antarctic Peninsula (**WITHDRAWN**)
6	Xavier Fettweis	Sensibility of the Greenland ice sheet surface mass balance simulated by the regional model MAR to the irreducible water saturation in snow and the pore hole close off density
7	Joel Harper	Challenges and Limitations of Using In Situ Observations to Assess Modeled Infiltration and Refreezing in Firn
8	Stan Jakobs	Effects of snow layer initialisation and soot concentration on meltwater retention
9	Leo Kampenhout	Firn modelling in the Community Earth System Model (CESM)

10	Horst Machguth	Greenland surface mass balance observations from the ice sheet ablation area and local glaciers
11	Ruth Mottram	The importance of retention and refreezing to the surface mass balance of small Arctic glaciers
12	Brice Noël	A downscaled 1km dataset of daily Greenland ice sheet surface mass balance components (1958-2015)
13	Ward van Pelt	The changing role of snow conditions and refreezing on mass loss of Svalbard glaciers
14	Baptiste Vandecrux	Understanding non-linear change in the permeability of firn on Greenland ice sheet
15	Melchior van Wessem	The simulated Surface Mass Balance of the Antarctic Peninsula

Participant List

No. of participants:				
50 Confirmed participants		Country	Affiliation	Email
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