How does the meltwater flow?

Insights from Retention MIP for firn hydrology

Danmarks Meteorologiske Institut

Uddannelses- og Forskningsministeriet

WHY?

- Different model estimates of SMB are similar but components differ

WHAT?

- Using **same** atmospheric forcing at 4 sites we compare parameterisations in:
  - 9 different 2D models driven by AWS data
  - 4 different 3D models driven by RCMs

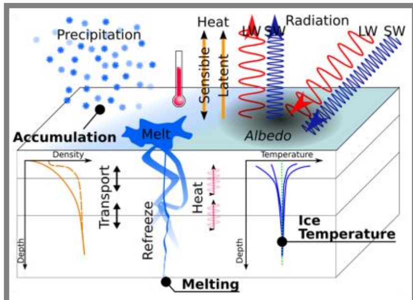
- **RESULTS:**

- No single model (or type) performed best at all sites
- Darcy's Law models and bucket schemes both work well at percolation zone sites
- Darcy's Law models perform best at ice slab sites
- Deep percolation models tend to overestimate percolation and deep firn temperatures but simulate recharge at firn aquifers well
- Simulated densities uncertainty of ±60 kg m^3 in dry snow zone and ±280 kg m^3 warmer sites
- Simulated temperatures uncertainty of ±14 °C in dry snow area and ±15-18 °C warmer sites

https://www.the-cryosphere-discuss.net/tc-2019-331/tc-2019-331.pdf

Ruth Mottram

Baptiste Vandecrux, Martin Olesen, Fredrik Boberg, Nicolaj Hansen, Peter Langen, Robert Fausto and RetMIP contributors



Greenland Ice sheet surface mass balance: Modelled values broadly agree but….

Contributor	Model	Publication [a]	Class [b]	Area (10^6 km^2)	Grid	SMB [c] (Gt/yr)	Precipitation [c] (Gt/yr)	Runoff [c] (Gt/yr)
Noël	RACMO2.3	[90]	RCM	1.73	11 km	350	721	311
Noël	RACMO2.3p2	[59]	RCM	1.73	11 km	432	727	258
Langen	HIRHAM5	[9]	RCM	1.71	5.5 km	385	794	351
Fettweis	MARv3.6	[22]	RCM	1.69	7.5 km	381	706	308
Noël	RACMO2.3d	[91]	RCM-d	1.69	1 km	314	755	397
Noël	RACMO2.3p2d	[59]	RCM-d	1.69	1 km	338	703	331
Cullather	MERRA-2	[92]	GA-n	1.73	0.5°	504	818	277
Hanna	ECMWF	[14]	GA-d	1.65	5 km	370	532	186
Wilton	ECMWFd	[93]	GA-d	1.71	1 km	314	603	246
Mernild	Snow Model	[94]	PM	1.64	5 km	125	655	418

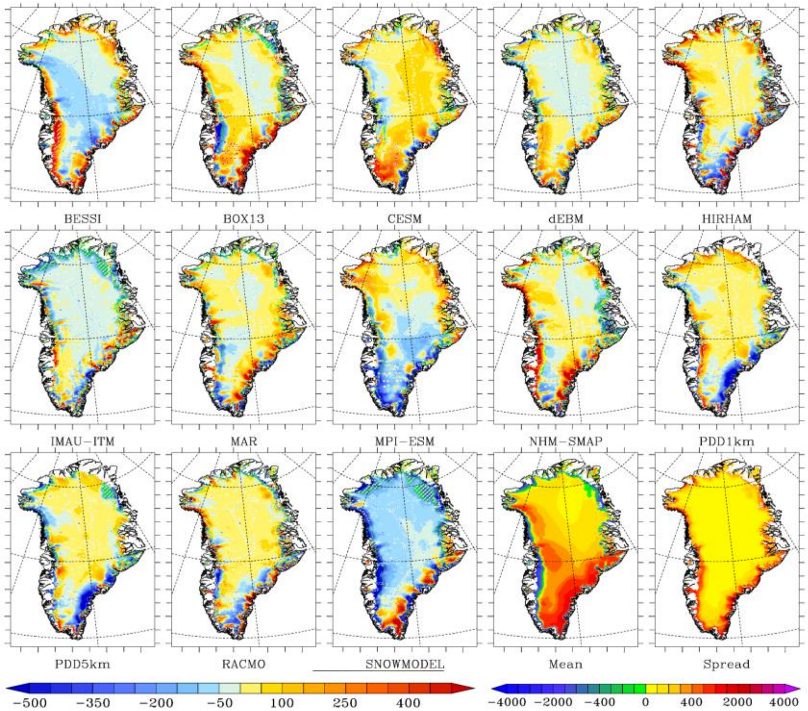
…the components differ significantly both integrated over the ice sheet.

IMBIE2; Shepherd et al., 2019

And spatially…

Fettweis et al., 2019 TCD

https://www.the-cryosphere-discuss.net/tc-2019-321/



RetMIPa: 9 models driven by AWS

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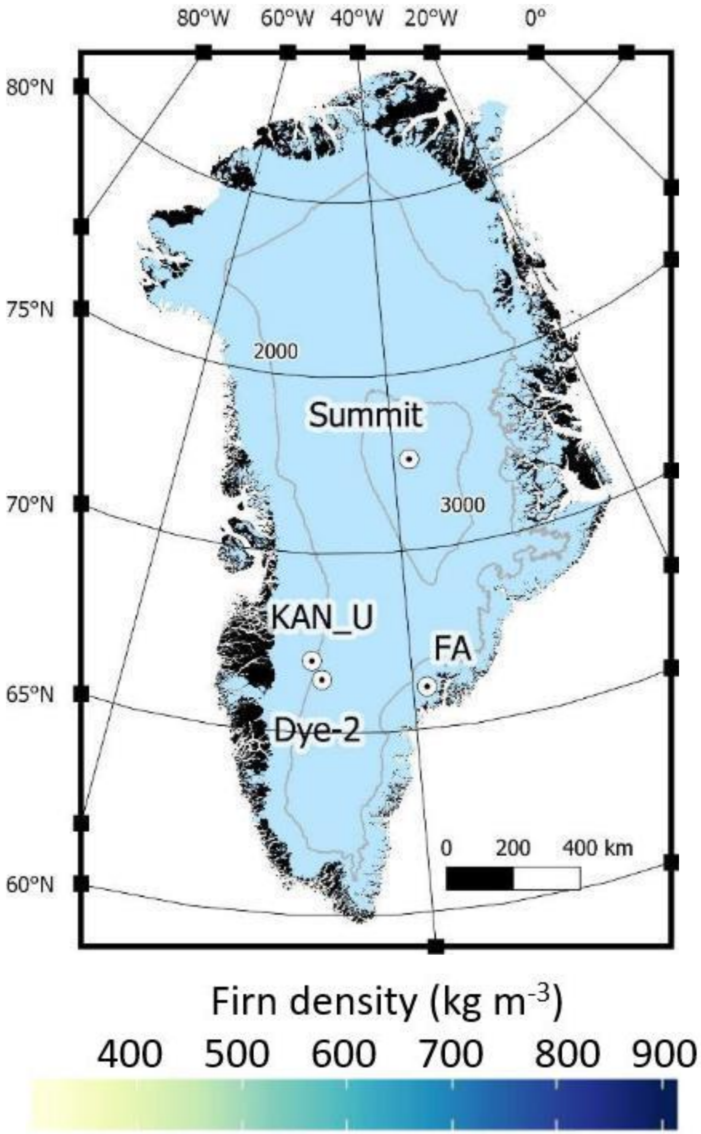
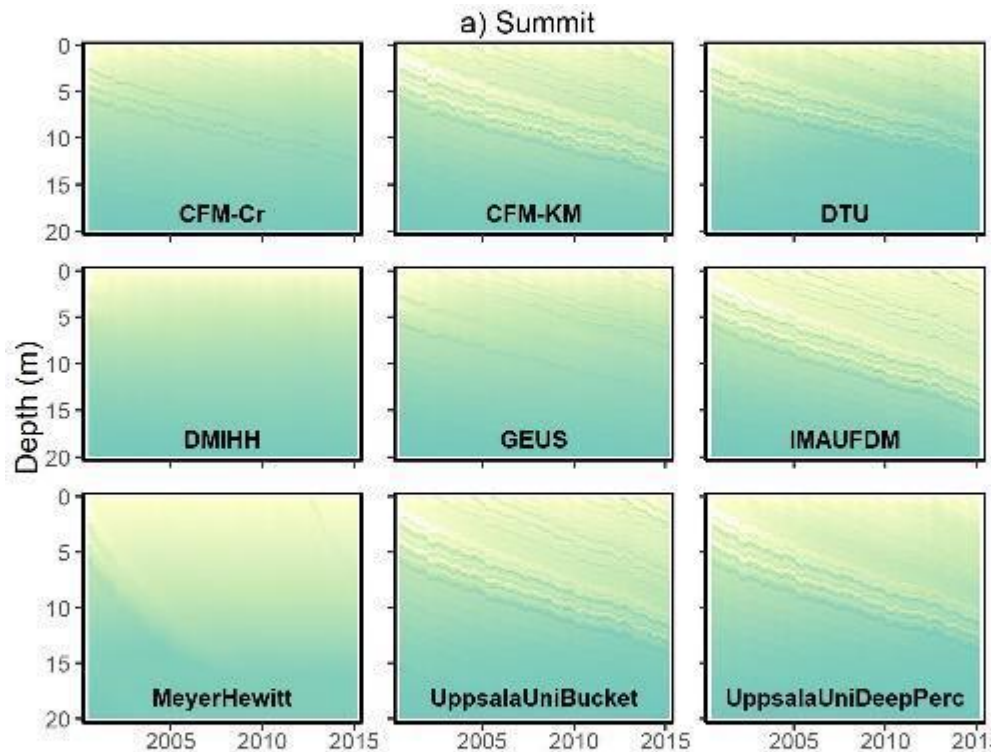
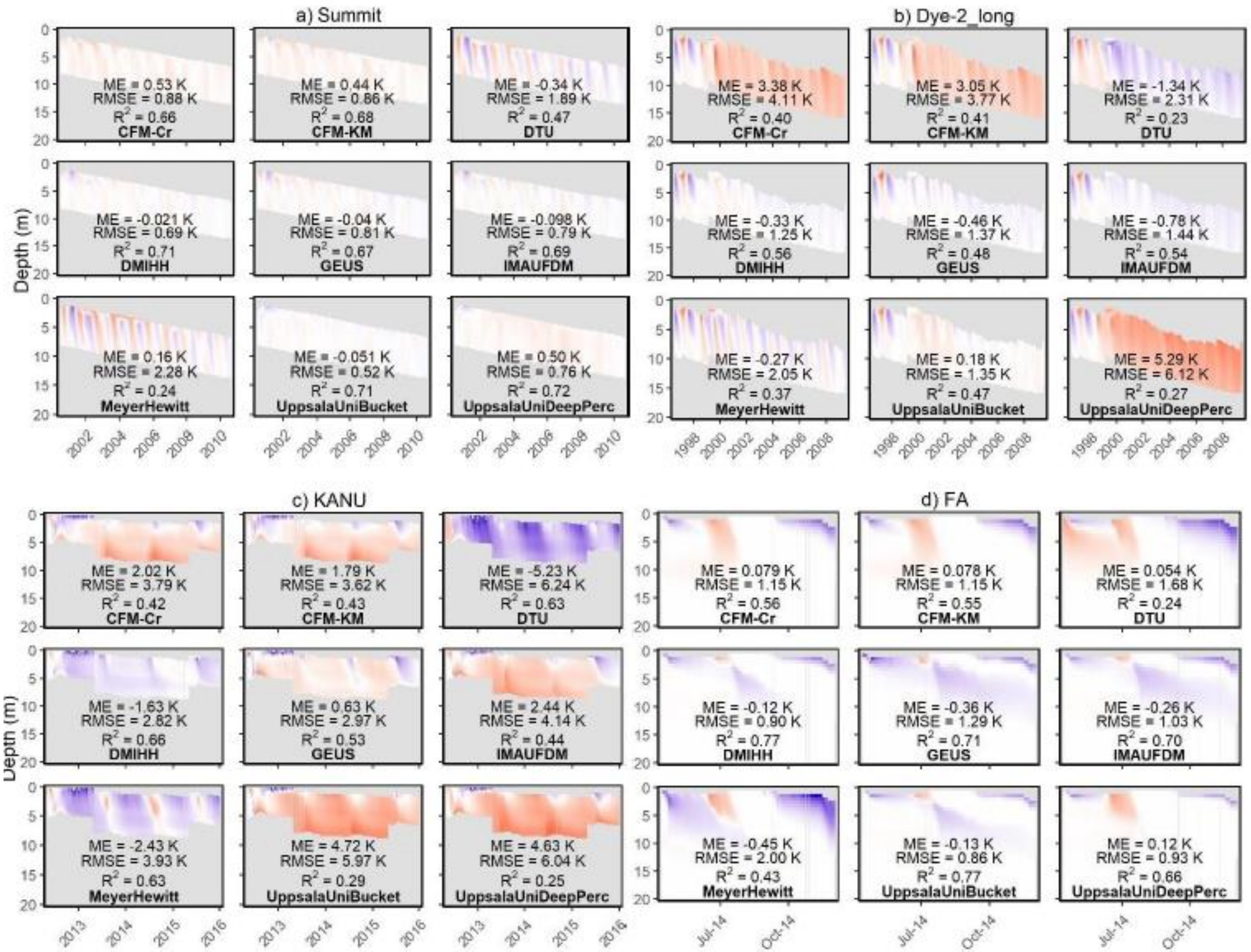


At Summit all models perform very similarly in terms of temperature, density, refreezing etc

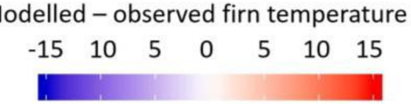


RetMIPa: Evaluation against observations

- Different models handle different parts of the ice sheet better.
- Dry snow zone is most uniform
- Percolation zone (KAN_U, Dye-2) have the largest differences



Modelled – observed firn temperature (°C)



 Vandecrux et al., 2019 TCD

RetMIP: Meltwater Percolation evaluation with upGPR at Dye2

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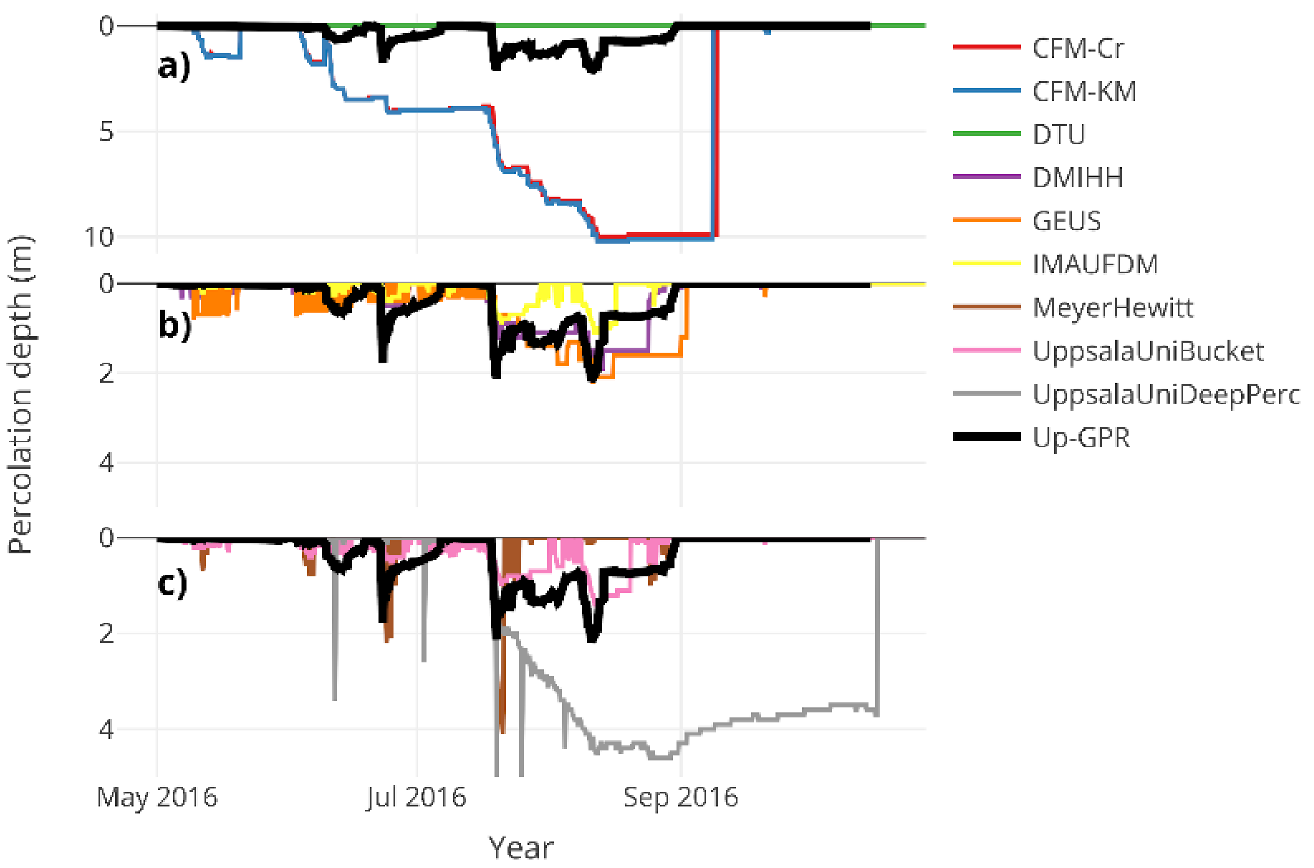
- Presence of ice layers strongly affects percolation depth, which in turn determines temperatures and refreezing capacity.
- Deep percolation model overestimate depth
- Very wide model performance which given they are driven by exact same data



Vandecrux et al., 2019 TCD

RetMIP:a Firn Temperatures

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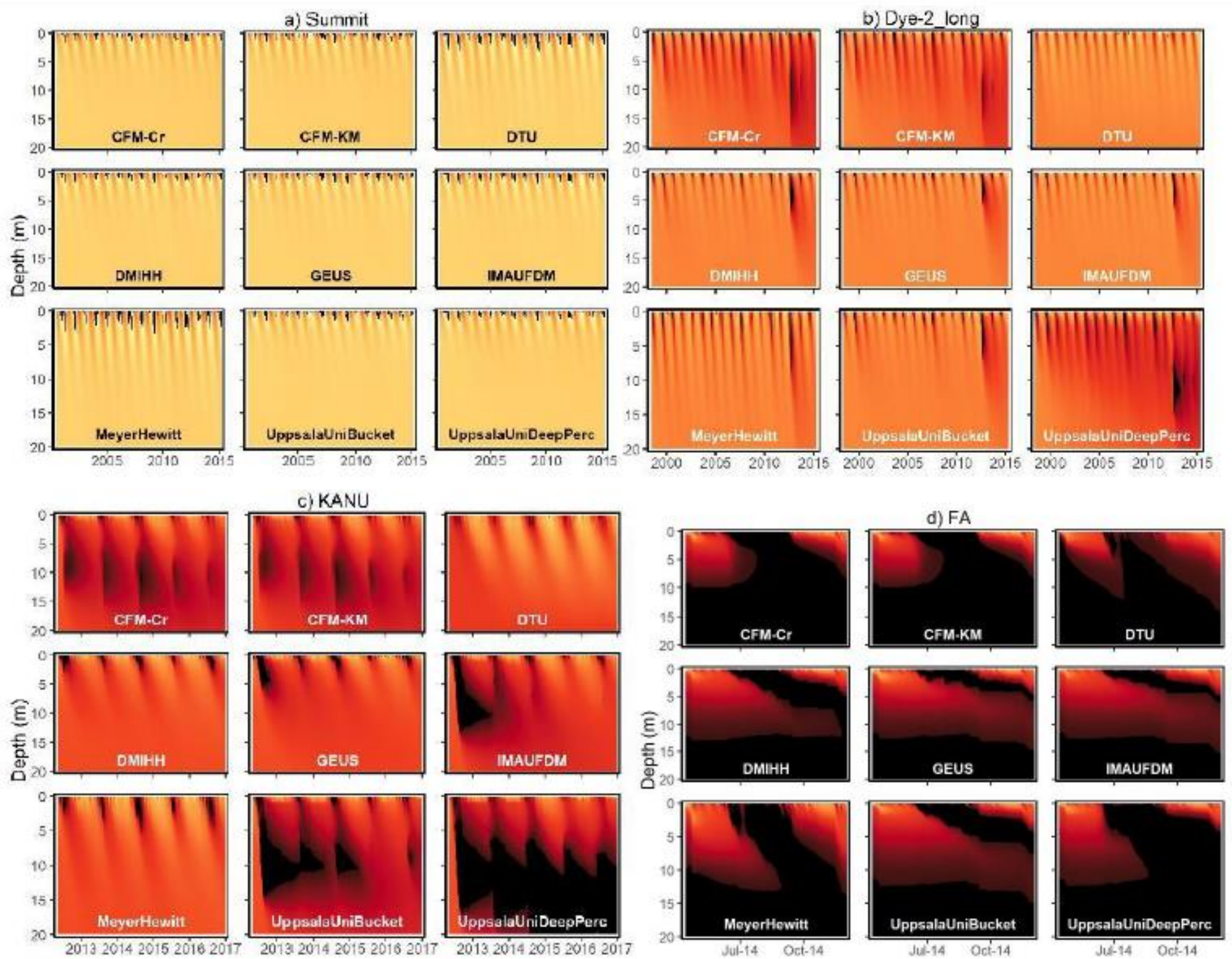
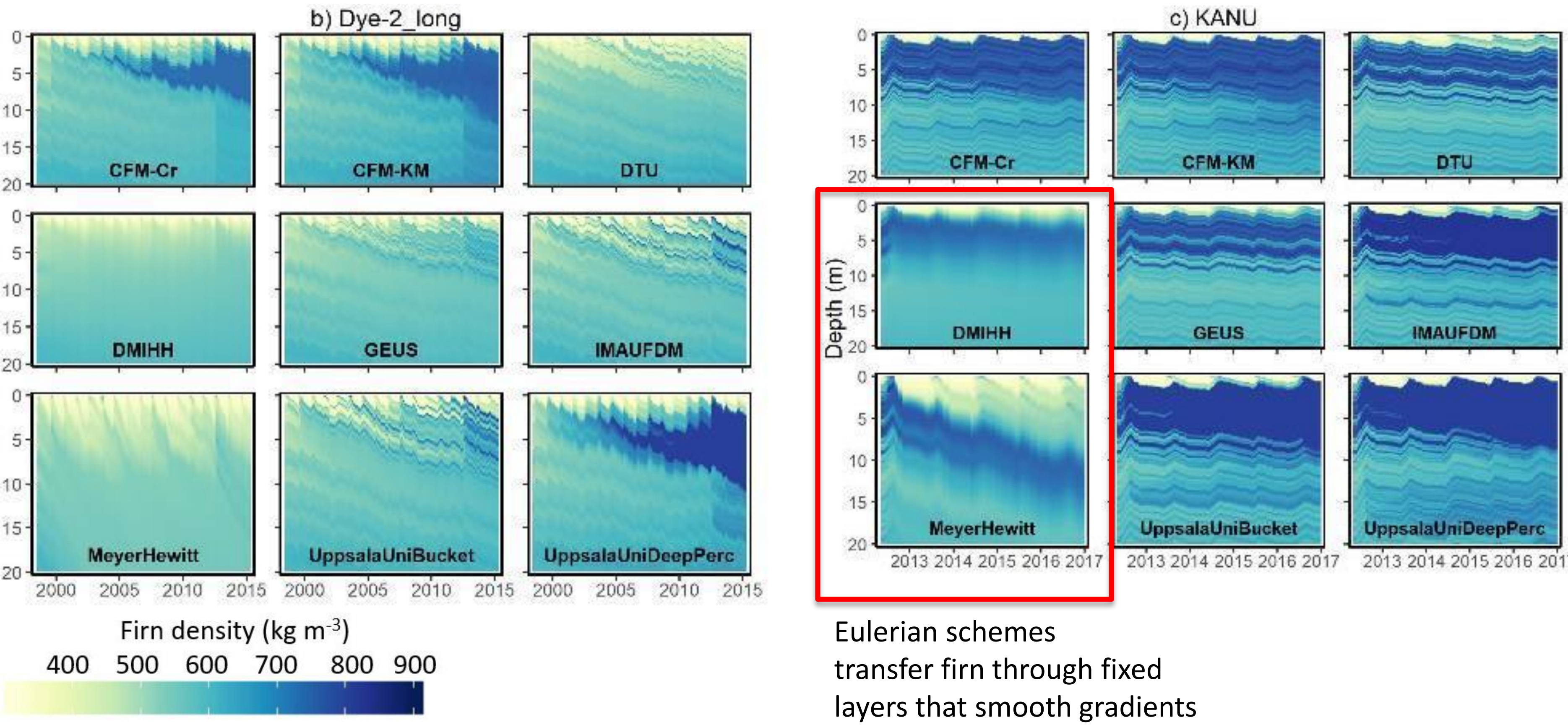
- Percolation scheme is very important for deep temperatures
- Where deep percolation is allowed, firn temperatures at depth become much warmer (implies less refreezing possible)



Vandecrux et al., 2019 TCD

RetMIPa: 9 models driven by AWS



Eulerian schemes transfer firn through fixed layers that smooth gradients through time

Vandecrux et al., 2019 TCD

RetMIPb: How do the RCMs do?

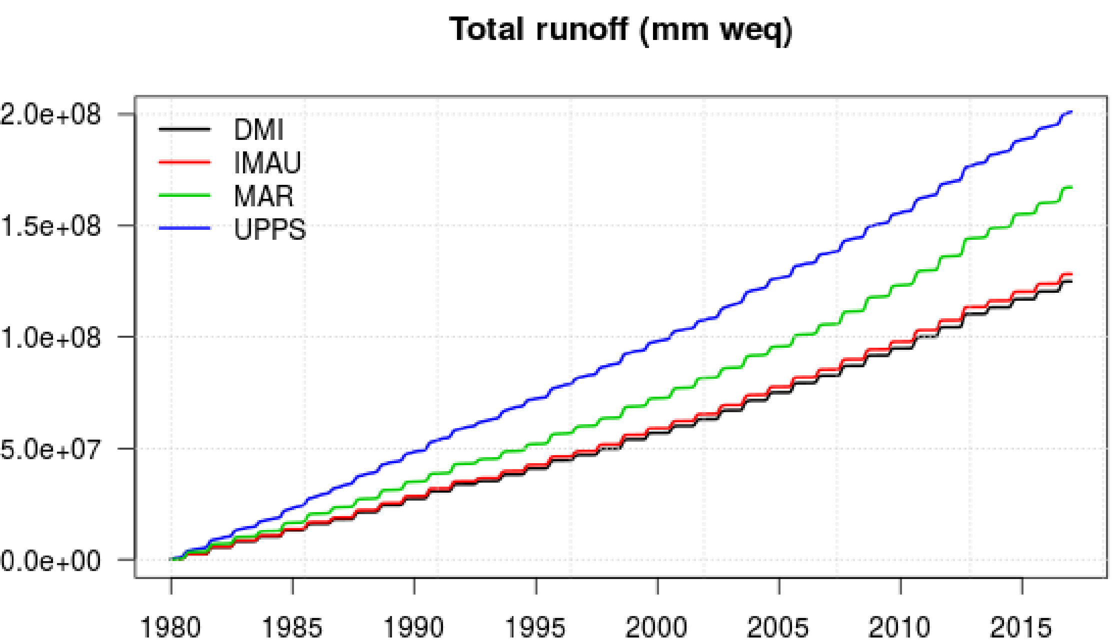
Forced with same atmospheric forcing (HIRHAM5 on RACMO 0.11 grid) but using subsurface scheme of each RCM

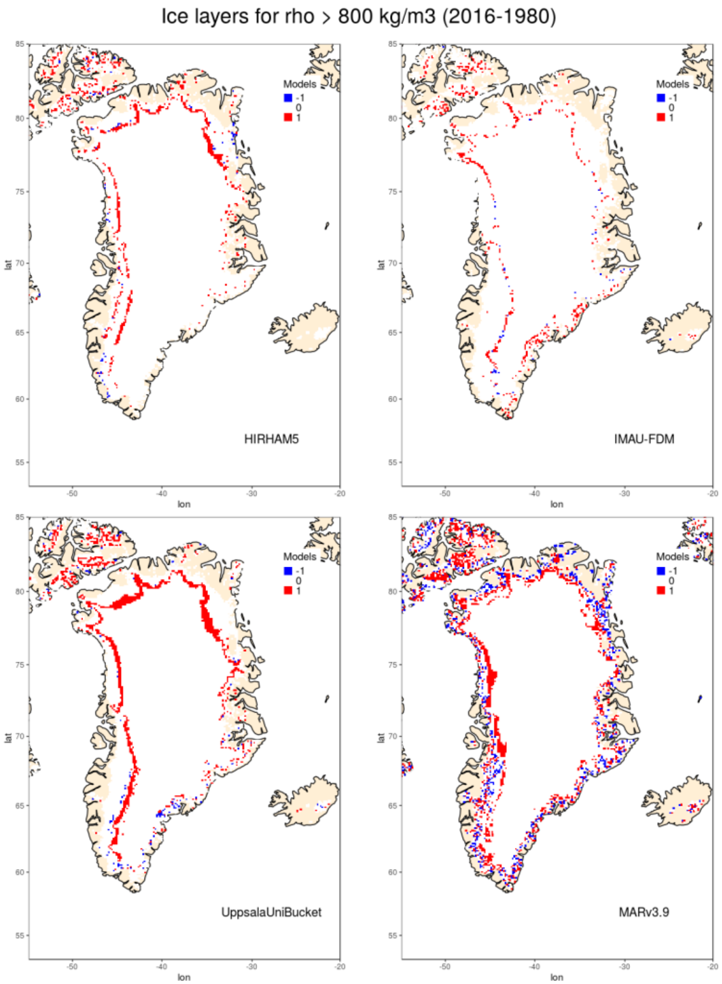
Accumulated runoff over the whole ice sheet for 1980-2016 period:

~**37%** more run-off in UPPS

~**28%** more runoff in MAR

than RACMO/HIRHAM models

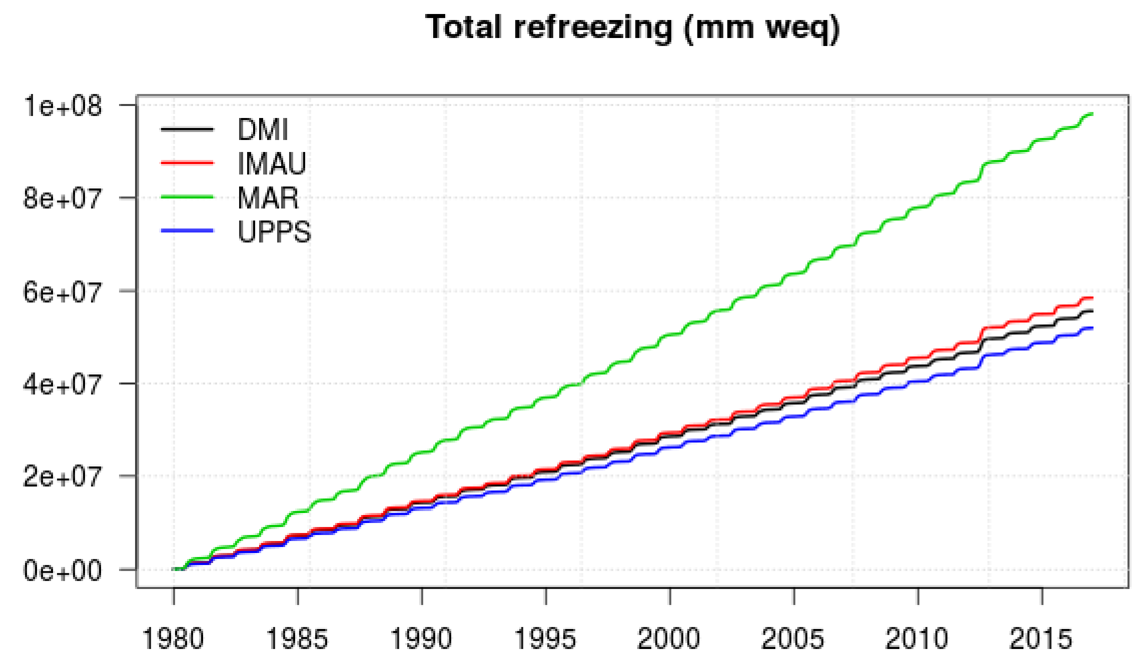


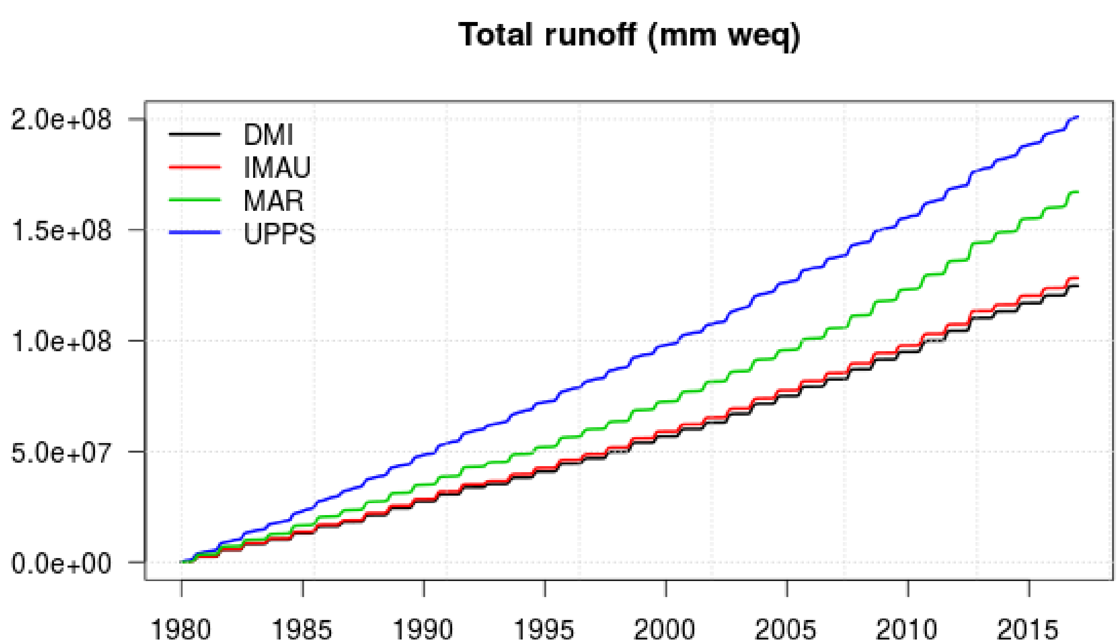


Mottram et al., in prep

Retention MIP

Accumulated runoff and refreezing summarized for the entire ice sheet from 1980 to 2016. (Experiments with 4 models run over whole ice sheet – same atmospheric forcing).





~**37%** more run-off in UPPS (Uppsala percolation model) and ~**28%** more runoff in MAR* than RACMO/HIRHAM accumulated over 1980-2016 period

*We are still investigating if there is a bug here!

Thanks to all RetMIP Contributors

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Model version	Model Identifier	Institute	1D/2D
HIRHAM5 subsurface	DMIHH	DMI	1D
HIRHAM5	HIRHAM	DMI	2D
HH_GEUS	GEUS	GEUS, DTU	1D
MeyerHewitt	MeyerHewitt	University of Oregon; University of Oxford	1D
Community Firn Model	CFM-Cr	University of Lancaster	1D
Community Firn Model	CFM-KM	University of Lancaster	1D
USGS SUTRA-ICE	SUTRA-ICE	USGS	1D
DTU-FIRN	DTU	DTU - Space	1D
UppsalaUni	UppsalaUniBucket	Uppsala University	1D
UppsalaUni	UppsalaUniDeepPerc	Uppsala University	2D
IMAU-FDM	IMAUFDM	IMAU, University of Utrecht	1D
MAR	MAR	University of Liege	2D
RACMO	RACMO	IMAU, University of Utrecht	2D

Supplementary Information:

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Preprint. Discussion started: 2 March 2020

The Cryosphere Discussions
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The firn meltwater Retention Model Intercomparison Project (RetMIP): Evaluation of nine firn models at four weather station sites on the Greenland ice sheet

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Results from the 2D sites are given in Vandecrux et al., 2019 TCD
https://www.the-cryosphere-discuss.net/tc-2019-331/tc-2019-331.pdf

Results from the 3D models are still in preparation

Experiments 1

5 pointwise runs driven by observed surface fluxes, initialized with and benchmarked against observed subsurface profiles of temperature and density.

Sites:

KAN_U (K)

Summit (S)

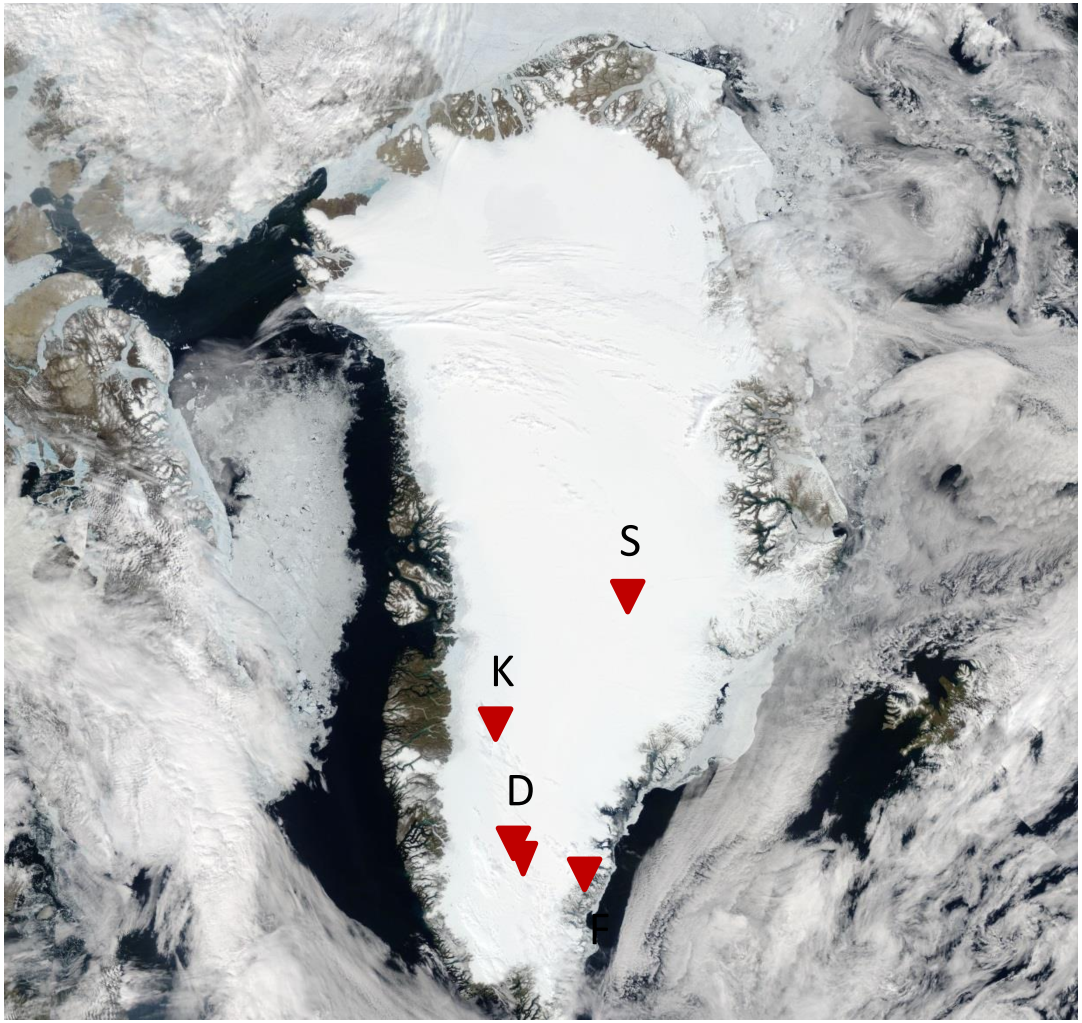
Dye-2 –long (D)

Dye-2-_16 (D)

Firn Aquifer (F)

Input data for the firn model

- Time stamp (i.e. beginning of each 3-h time step, DD-MMM-YYYY hh:mm:ss)
- Surface melt
- Net accumulation (P-E)
- Surface temperature



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Experiments 2

All models are run on the RACMO2 11 km 2D grid

Time-varying input data

Across the 2D grid, all models use HIRHAM5 output interpolated to the RACMO2 11 km grid supplied as 3 hourly inputs of:

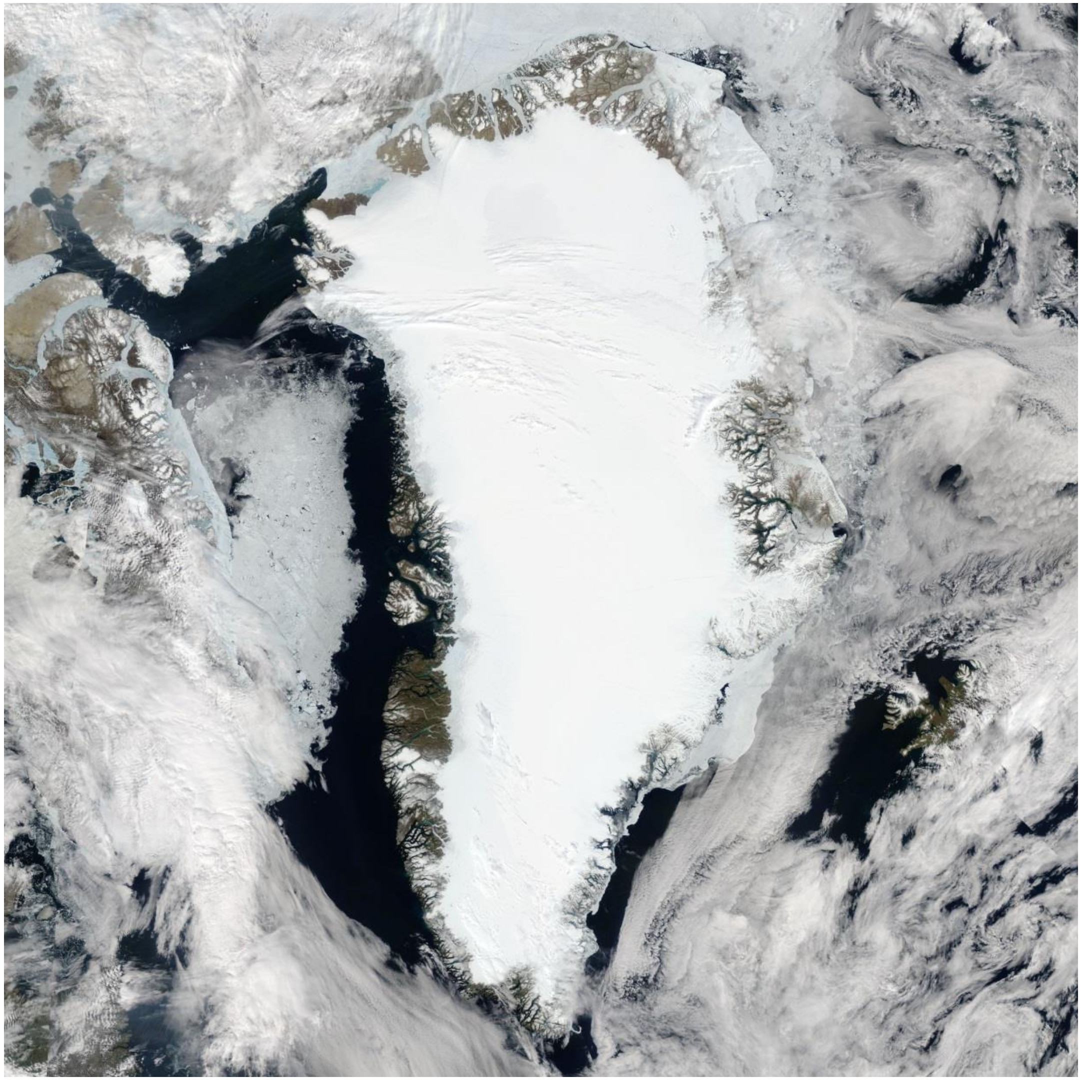
- Surface melt
- Rainfall
- net solid accumulation
- Skin temperature (tskin, K)

Time-constant input data

- Surface ("fresh snow") density of 315 kg / m3
- Elevation (elev, m)
- Long-term annual total accumulation
- Long-term annual average 2 m-temperature
- Lat-lon grid
- Ice mask

Initialization

- Each group uses their own initialization and loops repeatedly over the decade 1980-1989 until transients in decadal averages have disappeared.



Participating Models

Danmarks Meteorologiske Institut

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HIRHAM5 subsurface	DMIHH	DMI	1D
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IMAU-FDM	IMAUFDM	IMAU, University of Utrecht	1D
MAR	MAR	University of Liege	2D
RACMO	RACMO	IMAU, University of Utrecht	2D