RetMIP Protocol

To perform an intercomparison of meltwater retention, refreezing and runoff in different SMB and firn models without the complicating factors of different weather forcing at the surface, grids and glacier masks, we propose a coordinated experiment, where different firn models are driven by the same surface inputs of mass and energy.

Two streams of experiments are planned, and participants may take part in one or both of these:

- A set of 5 pointwise runs driven by observed surface fluxes, initialized with and benchmarked against observed subsurface profiles of temperature and density.
- An all-Greenland run on a common 11 km grid driven by surface fluxes from a regional climate model. Initialization is performed through a spinup.

In the following, we describe for both of these experiments, the site/domain, the input data provided, the initialization procedure for the subsurface modeling, the requested output variables and the file formats.

We realize that subsurface models are different and the input and output data described below may not be applicable to your setup – directly or, in fact, at all. You may not need to use all the supplied input data and many groups will need to make some amount of code changes to make their model work with the supplied input data. Finally, not all the requested output variables are available from all models, but please do try and provide as many of them as you can – possibly with some code changes or post-processing work.

The distributed input data and the collected output data will be made available to all participants.

Please indicate as soon as possible if you wish to participate, and please let us know which of the experiments you want to take part in (pla@dmi.dk).

1. Pointwise comparison

Site description

All important information regarding each site is given in Table 1.

Table 1: Information about the 5 sites considered in the point-wise model comparison.

Station name	**KAN_U**	**Dye-2_long**	**Dye-2_16**	**Summit**	**Firn Aquifer (FA)**
Start time	01-May-2012 00:00:00	01-Jun-1998 00:00:00	02-May-2016 00:00:00	02-Jul-2000 00:00:00	12-Apr-2014 00:00:00
End time	31-Dec-2016 06:00:00	02-May-2015 15:00:00	28-Oct-2016 09:00:00	08-Mar-2015 12:00:00	02-Dec-2014 21:00:00
Geographical location					
Latitude (degN)	67.0003	66.48001	66.48001	72.57972	66.1812
Longitude (degE)	-47.0243	-46.27889	-46.27889	-38.50454	-39.0435
Elevation (m a.s.l.)	1840	2165	2165	3254	1563
Forcing data					
Weather data	PROMICE, GAP and Charalampidis, et al., (2015)	GC-net (Steffen, et al., 1996)	Unpublished (Samira Samimi)	GC-net (Steffen, et al., 1996)	Unpublished (IMAU)
Surface energy balance	van As, et al., (2005)	van As, et al., (2005)	van As, et al., (2005)	van As, et al., (2005)	van As, et al., (2005)
Validation data:					
Firn temperature	Available at the station and Charalampidis, et al., (2015)	Available at the station	(Heilig, et al., 2018)	Available at the station	Available at the station
Firn density	Machguth, et al., (2016) and unpublished	Machguth, et al., (2016)	Unpublished	Albert (1996), Lomonaco, et al., (2011), Albert & Shultz (2002) Unpublished	None
Site specific constants					
Surface snow density (kg/m^3) [1]	315	315	315	315	315
1950-99 average annual accumulation (mm w.eq.) [2]	543	476	476	159	1739
1950-99 average annual air temperature (deg C) [3]	-12.4	-16	-14	-26	-7
Surface slope (deg) [4]	0.5	0.2	0.2	0	0.6
Observed deep firn temperature with observation depth (deg C)	-9 @5 m	-15.5 @10 m	-13 @9 m	-31 @10 m	0 @25 m

[1] Fausto, et al., (2018); [2] Box, et al., (2013); [3] Box, (2013); [4] Howat, et al., (2014)

The forcing data

The data from each weather station were quality checked and obvious sensor malfunction were discarded. The data gaps were filled using either nearby stations or HIRHAM5 data (more details in Charalampidis, et al., (2015) and Vandecrux, et al., (submitted)). Downward longwave radiation is not monitored by the GC-net stations (Dye-2_long and Summit) and is taken entirely from HIRHAM5 output. The surface energy balance developed by van As, et al., (2005) was used to calculate surface "skin" temperature, meltwater generation and mass fluxes. The data (originally hourly values) was averaged to three hourly values.

Input data for the firn model

For each site a csv file is provided with the following fields:

- Time stamp (i.e. beginning of each 3-h time step, DD-MMM-YYYY hh:mm:ss)
- Surface melt (variable name "melt_mmweq" , 3-hourly mean)
- Net accumulation, i.e. sum of snowfall, sublimation and deposition ("net_acc_mmweq ", 3-hourly mean)
- Surface temperature ("Tsurf_degC", 3-hourly mean)

Notes: Rain is not monitored at any site so it is not included in the mass fluxes. Time stamps give the beginning of each 3hr time steps.

The input files can be downloaded here:

http://ensemblesrt3.dmi.dk/data/prudence/temp/PLA/RetMIP_input/Pointwise1D/Input/Weather_data

Time-constant input data for boundary conditions

To allow comparison of the various firn models, the boundary conditions should be fixed. Table 1 gives the values of main boundary conditions and is also available a csv file. Modelling teams are free to choose any constant or boundary condition not specified here.

Note: For the firn models that need a prescribed temperature at the bottom of the firn column, we also provide the observed deep firn temperature derived from the station data. Even though the observation might come from a shallower depth, we believe it is a better boundary condition than, for example, mean air temperature.

The time-constant station-info file is found here:

http://ensemblesrt3.dmi.dk/data/prudence/temp/PLA/RetMIP_input/Pointwise1D/Input/station_info.csv

Initialization data

Initial profiles for density, temperature and liquid water content are provided in csv files with 10 cm resolution and down to 60 m. Profiles of temperature and density are given as average for each depth interval while liquid

water profile (only for site FA) is given as amount of water (mm) for each interval. The "depth" column indicates the bottom of each depth interval. Initial surface temperature can be taken as the first reading of the input surface skin temperature.

The origin of the initial density profiles are given in Table 2. Initial temperature profiles were calculated using the first reading of air temperature (as first guess of surface temperature), the first valid measurement of firn temperature, and the deep firn temperature (Table 1). Initial liquid water content at FA is calculated according to the observations from Koenig, et al., (2014) indicating pore saturation below 12.2m depth.

Table 2: Origin of the initial firn conditions.

Site	Initial firn density
KAN_U	Top 10 m: core_1_2012 (Machguth, et al., 2016) From 10 to 60 m: Site J 1989 (Kameda, et al., 1995)
Dye-2_long	DYE2 1998 core B (Mosley-Thompson, et al., 2001)
Dye-2_16	Top 18 m: Core_10_2016 (unpublished) From 10 to 60 m: DYE2 1998 core B (Mosley-Thompson, et al., 2001)
Summit	Top 8m: core from 1990 by Mayewski & Whitlow., (2016) From 8 to 60 m: GRIP core
FA	Top 8 m: FA-14 (unpublished) From 8 to 60 m: FA-13 (Koenig, et al., 2014)

Note: Other quantities needed to initialize the model (eg. grain size, firn conditions at greater depth etc.) are determined by the groups. Please document these initializations when you submit the results.

The initialization data is found here (with sub-directories):

http://ensemblesrt3.dmi.dk/data/prudence/temp/PLA/RetMIP_input/Pointwise1D/Input/InitialData/

Output

The following quantities are saved as output every 3 hr and interpolated to a common vertical grid (top 20 m in 10 cm spacing) as 3 hourly averages:

Variable name	**Description**	**Unit**
temp	Temperature	K
rho	Density	kg/m3
lwc	Liquid water content	mm weq
icecon	Ice content	mm weq
rfrz	Refreezing	mm weq / 3h

and as total values over the whole firn column:

Variable name	Description	Unit
trunoff	Total runoff	mm weq / 3h
trfrz	Total refreezing	mm weq / 3h
tfac	Total firn air content	m
tlwc	Total LWC content	mm

Output data will be in NetCDF (.nc not nectdf4) and will be aggregated in 2 files:

- Gridded values (temperature, densities…) should be all combined in a file called:

  RetMIP_[GroupOrModelIdentifier]_[SiteName]_3hourly_columns.nc

  With each variable accessible by the variable name listed above

- Daily values (total runoff, total refreezing …) should be all combined in a file called:
  RetMIP_[GroupOrModelIdentifier]_[SiteName]_3hourly_values.nc

  With each variable accessible by the variable name listed above

Note:

- If your firn model runs at a different temporal resolution, please notify us and interpolate the outputs to the original 3 hourly resolution to facilitate the comparison between models.
- Time should be given as days since 1900-01-01 00:00:00, or some other relative time axis (hours or days since YYYY-MM-DD HH:HH:SS)

Example files are found here:

http://ensemblesrt3.dmi.dk/data/prudence/temp/PLA/RetMIP_input/Pointwise1D/Output_example/KAN-U/

2. Greenland-wide run

Domain

All models are run on the RACMO2 11 km 2D grid using common ice mask, topography etc. Experiments will run over 1980-2016.

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 (melt, mm weq /3hr)

- Rainfall(rain, mm weq /3 hr)
- Snow-plus-sublimation, deposition, condensation, evaporation, aka net solid accumulation (solidacc, mm weq /3 hr)
- Skin temperature (tskin, K)

Time-constant input data

Surface ("fresh snow") density shall be set to 315 kg / m3 everywhere (Fausto et al., 2018). Across the 2D grid, the following time-constant quantities will be supplied:

- Elevation (elev, m)
- Long-term annual total accumulation (accann, mm weq /yr)
- Long-term annual average 2 m-temperature (tann, K)
- Lat-lon grid
- Ice mask (as in HIRHAM5, Langen et al. 2017, interpolated to RACMO2 11 km grid).

Initialization

No initial profiles are supplied. Instead each group uses their own initialization and loops repeatedly over the decade 1980-1989 until transients in decadal averages have disappeared.

Output

Saving and collecting daily 3D fields (columns in all 2D points) is not feasible and we will instead focus on daily 2D fields of

Variable name	**Description**	**Unit**	**Average, snapshot or sum**
T10m	Temperature at 10 m depth	K	daily average
D550kg	Depth of 550 kg /m3 surface[1]	m	end-of-day snapshot
D830kg	Depth of 830 kg /m3 surface[1]	m	end-of-day snapshot
P20m	Pore space in top 20 m	m	end-of-day snapshot
lwctot	Total column LWC	m	end-of-day snapshot
runoff	Total column runoff	mm weq /day	daily sum
rfrz	Total column refreezing	mm weq /day	daily sum

[1]Determined by interpolation using the bulk density of the snow/firn and ice fractions of the layers. If this is below the bottom of the model, give missings

To track existence, depth and thickness of ice lenses and perennial firn aquifers, we will also collect **annual end-of-april snapshots** of the 3D fields of the following interpolated to 1 m resolution in the vertical down to 50 m (or less if the model does not reach 50 m, in which case you should just add missings below your lowest depth):

Variable name	**Description**	**Unit**
temp	Temperature	K

rho	Density	kg/m3
lwc	Liquid water content	kg water / kg ice+snow
icecon	Ice content	kg ice / kg ice+snow

File formats

- Input data will be in NetCDF (.nc), have all 3 hr time steps for a particular variable collected in one file annually and the naming convention will be:
  RetMIP_2Dinput_[variable]_[YYYY]_3hr.nc
  Download from (1 Gb / variable / year):
  http://ensemblesrt3.dmi.dk/data/prudence/temp/PLA/RetMIP_input/GrISwide2D_3hr/
  Time-constant fields:
  http://ensemblesrt3.dmi.dk/data/prudence/temp/PLA/RetMIP_input/GrISwide2D_TimeConstant/RetMIP_2Dinput_TimeConstant.nc

- Output data will be in NetCDF (.nc), have all daily time steps for the variable collected in one file annually and the naming convention will be:
  2D daily: *RetMIP_2Doutput_Daily_[GroupOrModelIdentifier]_[variable]_[YYYY].nc*
  3D annual: *RetMIP_3Doutput_Annual_[GroupOrModelIdentifier]_[variable]_[YYYY].nc*
  See dummy 3D file here:
  http://ensemblesrt3.dmi.dk/data/prudence/temp/PLA/RetMIP_input/GrISwide2D_TimeConstant/RetMIP_3Doutput_Annual_DummyGroup_DummyVariable_DummyYYYY.nc

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