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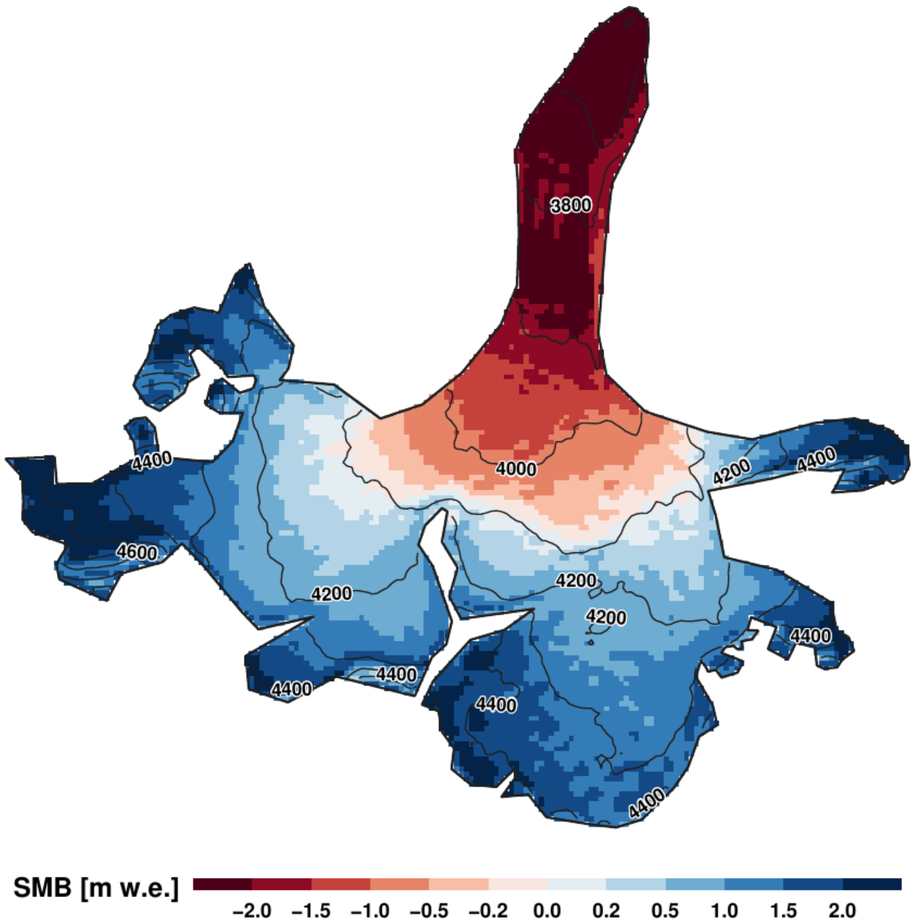
DMBSim v1.0

Tutorial 2: simulation of multi-year glacier mass balance



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1 Introduction

In this second tutorial we are going to simulate the mass balance of Abramov glacier (Pamir Alay) from 1980 to 1994. Compared to the first tutorial, we will use some additional features of the model:

- Multiple input files for different years
- Surface type with also firn and debris
- Advanced configuration with annual parameters
- Simulation of years with no measured mass balance

Note: to follow this tutorial you should be **already familiar with** the procedures of **tutorial 1.**

2 Input files

To prepare the input files we use the same methods explained in **section 3 of tutorial 1.** The input files will go in the model folder, under *input\abramov*.

- The **meteo** and **mass balance** files are provided together with this tutorial, under *tutorial2_input\abramov*. The mass balance file contains annual stake measurements from 1986/87 to 1989/90.
- On the **EarthExplorer** portal there is a good Landsat-5 image of the Abramov region taken on 22 August 1988, so we will create a **glacier outline shapefile** for the year 1988. The satellite image is located under **Data Sets** → **Landsat** → **Landsat Collection 2 Level-2** → **Landsat 4-5 TM C2 L2**, and is called LT05_L2SP_152033_19880822_20200917_02_T1. We download **band 3** ("...SR_B3.TIF").
- In QGIS or ArcGIS we **draw the glacier outline** and we save it as a shapefile, called *outline_abramov_1988.shp*.
- The model can use information on the **firn area** and the **debris cover** to make a better simulation of mass balance. On the satellite image of Abramov, we can see the late-summer snow line and the debris cover, so we can draw them:
  - We make a copy of the glacier outline shapefile.
  - We edit the glacier outline to **remove the glacier tongue,** leaving only the firn area. In QGIS, we can use the **Vertex Tool** to remove the glacier tongue (Fig. 1).
  - We save the new file as *firn_abramov_1988.shp*.
  - We make another copy of the outline shapefile.
  - We edit the outline polygon to cover **only the debris** on the tongue.
  - We save the new file as *debris_abramov_1988.shp*.
  - The three shapefiles are shown in Fig. 2.
- The glacier area changes over time (retreat of the tongue). The model can use **different outline files** (up to one per each year) to follow these glacier changes. We create a **second outline shapefile** corresponding to year 1994:
  - From the EarthExplorer we download image LT05_L2SP_152032_19940823_20200913_02_T1 (band 3, from 23 August 1994) and we load it into QGIS or ArcGIS.
  - To create the outline, we can **simply modify the 1988 outline.** We start by making a copy of *outline_abramov_1988.shp*.
  - We **adjust the tongue** (Vertex Tool, as in Fig. 1) so that it covers the 1994 extent (Fig. 3).
  - We save the shapefile as *outline_abramov_1994.shp*.
  - On the image there is **not a big change of firn and debris,** so we don't make new shapefiles for firn or debris: we will **re-use the shapefiles from 1988.**
- For the **DEM**, we download the ASTER file ASTGTMV003_N39E071 (GeoTiff format).
- As in the first tutorial, we open program *make_input.R* with RStudio and we click on **Run App**.
- First we make the input for year 1988:
  - **glacier name** *abramov*
  - **model year** 1988

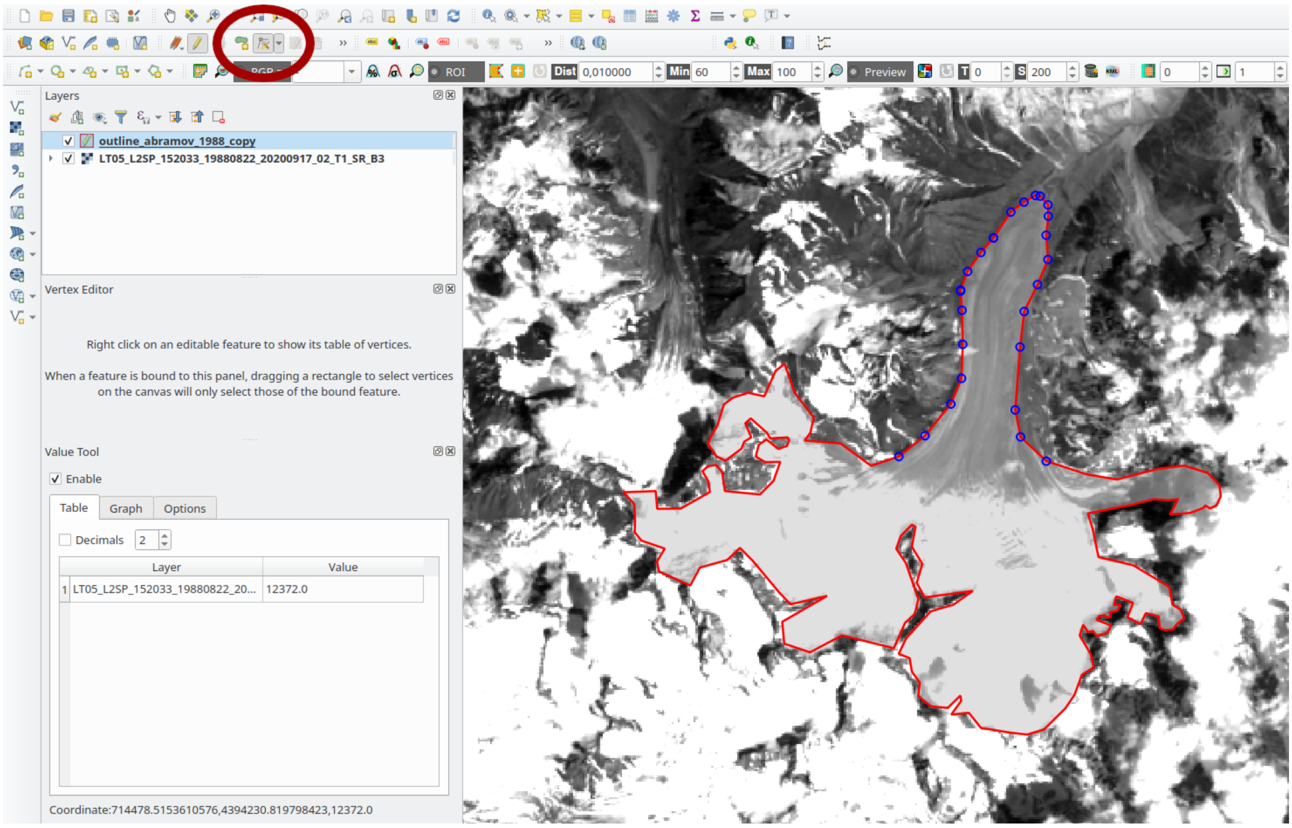

Figure 1: Editing the glacier outline to create the firn shapefile in QGIS.

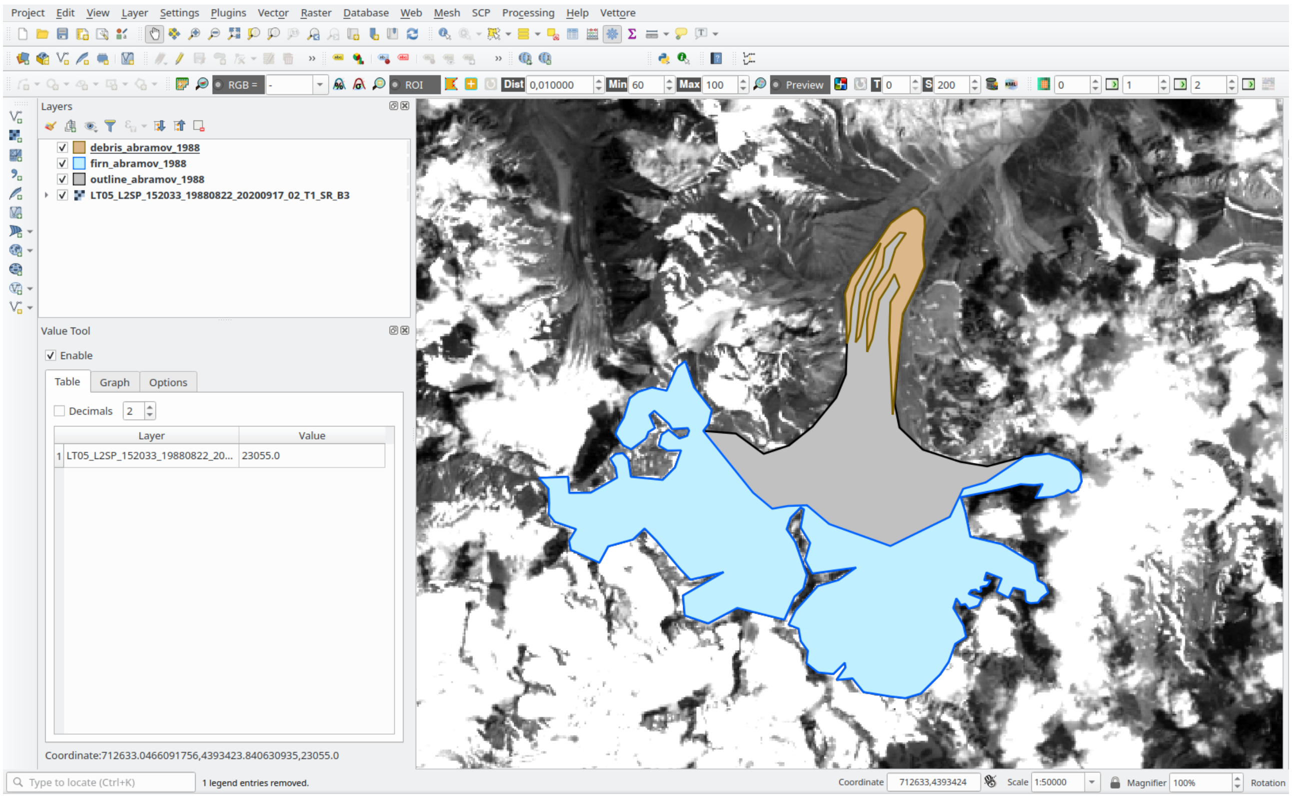

Figure 2: The outline (grey), firn (blue) and debris (yellow) shapefiles at Abramov for year 1988.

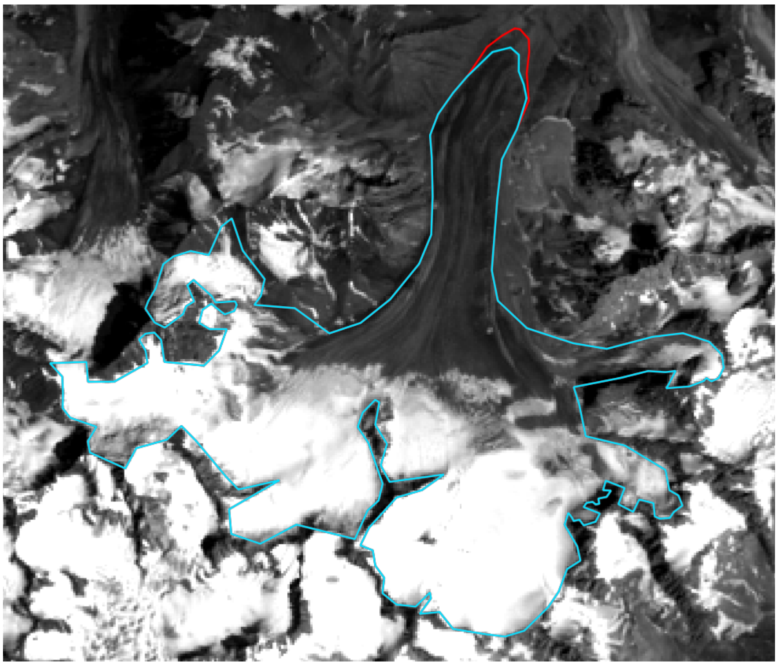

Figure 3: The 1988 (red) and 1994 (blue) outlines of Abramov glacier. Note that most of the 1988 outline is covered by the 1994 one.

  - **DEM file** *ASTGTMV003_N39E071_dem.tif*
  - **glacier shapefile** *outline_abramov_1988.shp*
  - **firn shapefile** *firn_abramov_1988.shp*
  - **debris shapefile** *debris_abramov_1988.shp*
  - **margin size** 500 m
  - **grid cell size** 50 m
  - Check **compute radiation.**

- We click on **RUN**
- When the processing is finished, we close the *make_input* window and we click again on **Run App** to make the input for year 1994.
- For year 1994 we use the following input:
  - **glacier name** *abramov*
  - **model year** 1994
  - **DEM file** *ASTGTMV003_N39E071_dem.tif*
  - **glacier shapefile** *outline_abramov_**1994**.shp*
  - **firn shapefile** *firn_abramov_1988.shp*: as said before, **we use again the same firn** of 1988
  - **debris shapefile** *debris_abramov_1988.shp*: as said before, we use again the **same debris** of 1988
  - **NOTE:** for the first time, we also use the **reference grid file** button. We select the file located under *utils\abramov\dhm\dhm_abramov_1988.tif*. The **reference grid file** is used to **align** the 1994 files **to the same area** of 1988. The model can also work without this, but it will be **faster and more accurate** if we use it
  - **margin size** 500 m

- **grid cell size** 50 m
- Don't check **compute radiation**: we use again the **same radiation** of 1988.

▪ When *make_input* has finished, we move the *utils**abramov*\\ folder to the model folder, under *input*\\.

▪ The input folder (*input**abramov*\\) looks like Fig. 4.

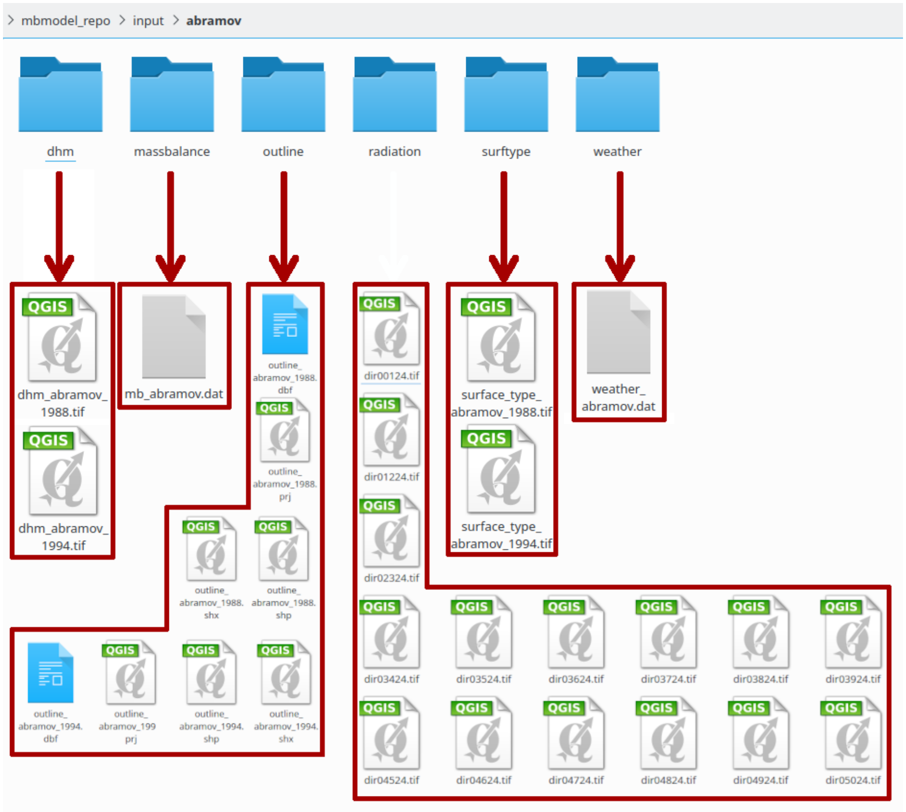

Figure 4: The folder *input**abramov*\\ after preparing all the input data.

3 Model parameters

As usual, parameters are set in file *set_params.R*. We set the main parameters as in Table 1:

Table 1: main model parameters.

Parameter name	Value	Explanation
name_glacier	"abramov"	Glacier name
filename_weather	"weather_abramov.dat"	Name of the meteo file
file_weather_nskip	2	Number of lines to skip in the meteo file
grids_crs	32642	EPSG code of the coordinates system
filename_massbalance_annual	"mb_abramov.dat"	Name of the file with the annual mass balance measurements
filename_massbalance_winter	""	Name of the file with the winter mass balance measurements. We don't have this so we leave it empty ("")
weather_aws_elevation	3837	Altitude of the meteo data.
first_year	1980	First year that we want to simulate: 2020
last_year	1994	Last year that we want to simulate

Compared to tutorial 1 we set **some additional parameters** (Table 2):

Table 2: additional model parameters for the Abramov multi-year simulation.

Parameter name	Value	Explanation
weather_max_precip_ele	4600	On a glacier, **precipitation** usually **increases** with altitude, but **only up to a certain limit,** above which it decreases. This parameter defines that limit (in meters a.s.l.)
model_avalanche_dates	c("3/31", "6/30")	This parameter defines the **dates at which an avalanche is simulated,** as "month/day". The avalanche redistributes snow at the base of steep slopes. **Note the *c*** at the beginning, which is used to combine the values. To remove avalanches completely, we would simply use c().
debris_red_fac	0.9	This parameter defines the **reduction of melt** for glacier cells which are covered by debris (supraglacial **moraine**). 1 = no reduction, 0.5 = melt is reduced by half.
default_prec_corr	300	Precipitation measured at a meteo station is usually underestimated **(precipitation undercatch)**. This parameter defines a **precipitation correction** in percent (100 = no correction, 200 = double the precipitation).
default_prec_summer_fact	0.7	Precipitation undercatch at a meteo station can be a bigger problem in winter than in summer. This parameter **reduces the previous precipitation correction** from May to September (1 = no reduction, 0.5 = reduction by half)
nodata_years_automatic	TRUE	This parameter tells the model **what to do with the years which have no mass balance measurements.** TRUE = use the mean optimized parameters from the years which have data, FALSE = use the values from *set_params.R* (like default_melt_factor).

4 Running the model

We run the model as in tutorial 1, by opening file *main.R* in RStudio and clicking on *Source*. The model output is stored under *output**abramov*\\. After the model has finished, we can see a **summary of the simulation results** under *output**abramov**overview.pdf*. Figure 5 (from *overview.pdf*) shows the model parameters optimized for each year. Note how the years with no data have a constant value which corresponds to the mean of the other years: this is the effect of parameter nodata_years_automatic (Table 2). Figure 6 shows the cumulative annual mass balance over the modeled period. The years with no data have a dashed line.

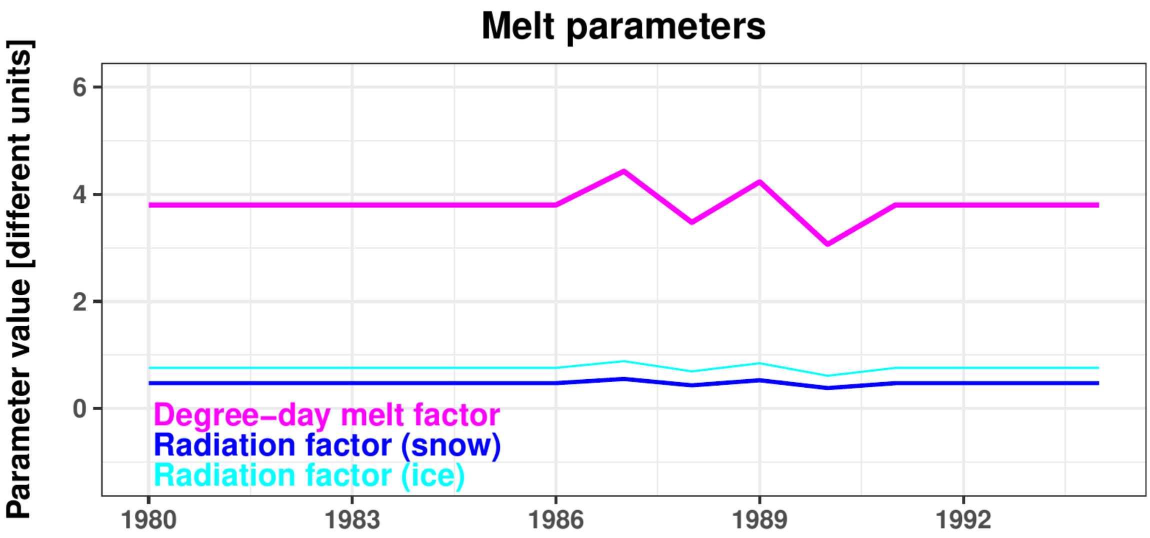

Figure 5: optimized model parameters for the multi-year simulation.

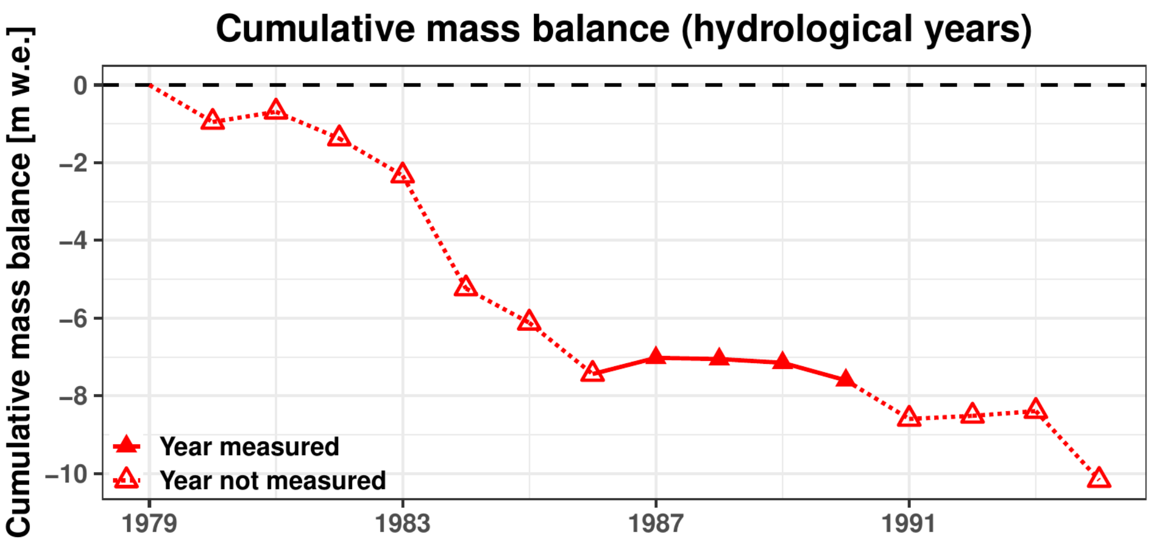

Figure 6: cumulative annual mass balance over the modeled period.

5 Improving the simulation

The plot of the simulated RMS errors (Fig. 7) shows that in the years 1987/88 and 1989/90 the model performed less well than the other years (RMS is higher). If we look at the **detailed annual results** (Fig. 8, in *output\abramov\annual_results*), we can see that **the error depends on the altitude:** the modeled mass balance is too low near the glacier source, and too high on the glacier tongue. We can improve the simulation by **changing some parameters for these years only.** To change these annual parameters, we create a new folder under *input\abramov*, called *params*. Inside we put a new file called *param_1988.dat*, with the content shown in Fig. 9. In this example, we change both the precipitation correction and the gradient of precipitation with altitude. In general, the parameter file can change any of the parameters of Table 3. If the model finds a **parameter file** for a certain year, these values are used **instead of** the ones from ***set_params.R.*** An example of a full parameter file is shown in Fig. 10. In the parameter file all lines starting with an asterisk (*) are ignored. For 1989/90, we use just one annual parameter: prec_corr = 310. We put it in a file called *param_1990.dat*. Then **we run the model again** and we see that the simulation is improved (lower RMS for these years).

Table 3: parameters which can be set for a specific year in the annual parameters file (also see Table 2).

Parameter name	**Unit**	**Explanation**
prec_corr	%	Precipitation correction
prec_elegrad	% / 100 m	Gradient of precipitation with altitude
prec_summer_fact	-	Reduction of precipitation correction in summer
temp_elegrad	°C / 100 m	Gradient of air temperature with altitude
melt_factor	mm w.e. / (°C day)	Melt factor for temperature
rad_fact_ice	10^{-3} mm w.e. / (°C hour (W m^{-2}))	Ice melt factor for solar radiation
rad_fact_snow	10^{-3} mm w.e. / (°C hour (W m^{-2}))	Snow melt factor for solar radiation

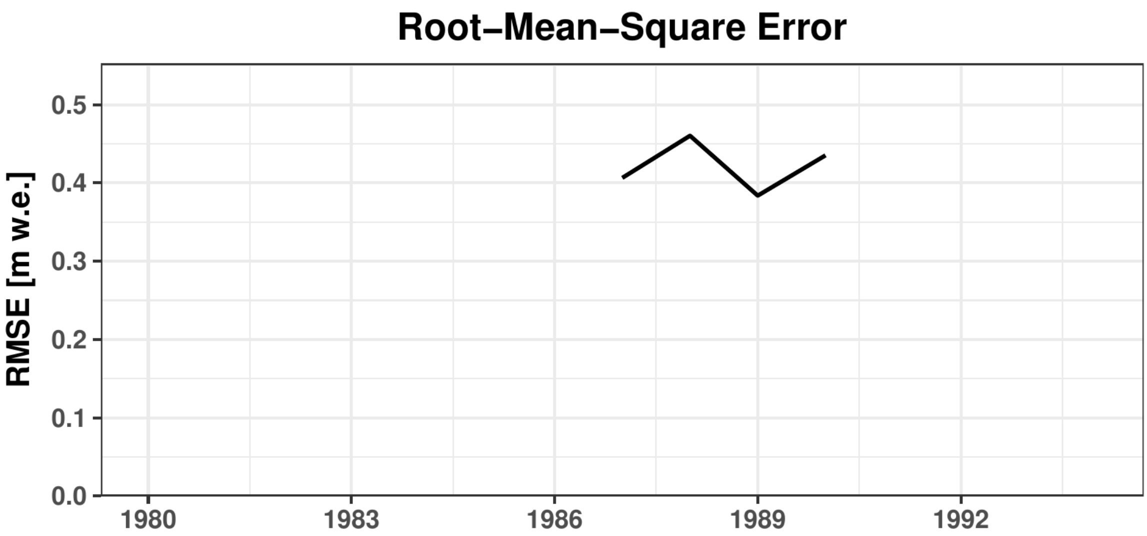

Figure 7: RMS error for the multi-year simulation.

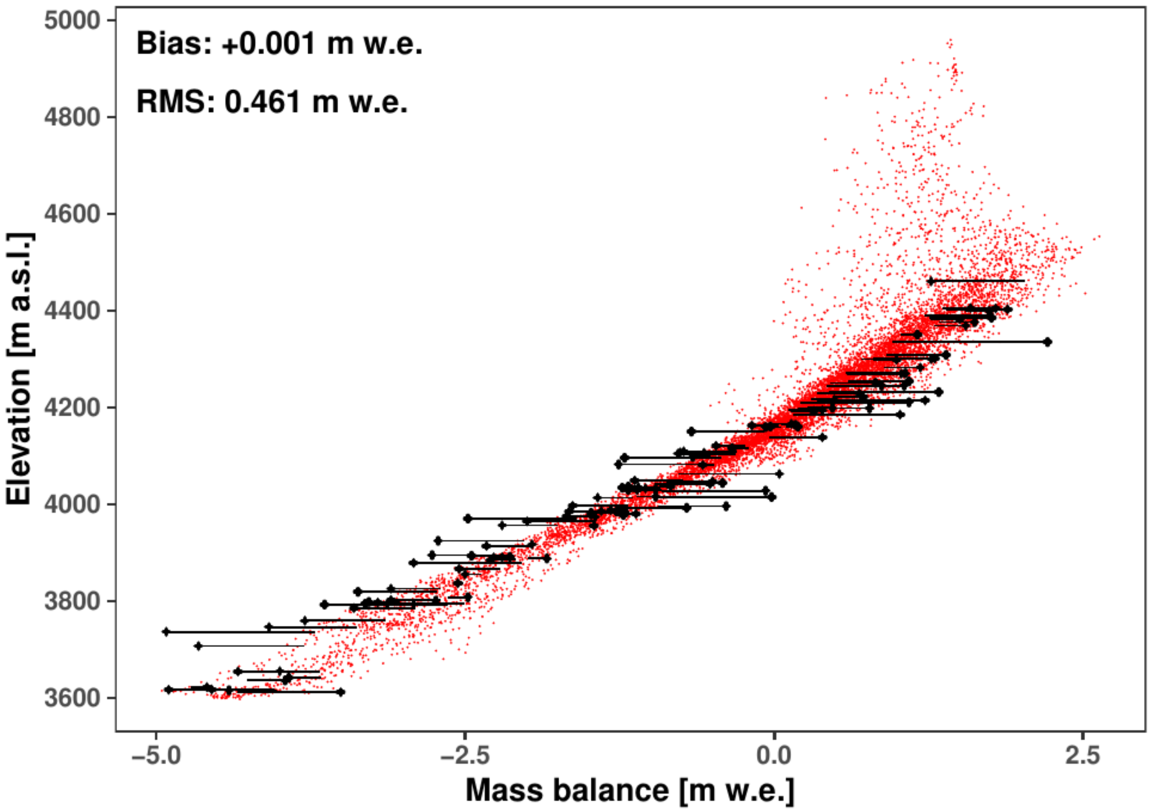

Figure 8: modeled mass balance profile (red) and stake measurements (black) for year 1987/1988.

param_1988.dat

```
* Input parameters for mass balance model
* Format: <value> ; <unit> ; <parameter name> ; <description>
*
* Accumulation
330     ; [%]                               ; prec_corr         ; precipitation correction
8       ; [% / 100m]                        ; prec_elegrad      ; precipitation gradient
*

```

Figure 9: parameter file for year 1988.

```
* Input parameters for mass balance model
* Format: <value> ; <unit> ; <parameter name> ; <description>
*
* Accumulation
1000    ; [%]                               ; prec_corr         ; precipitation correction
20      ; [% / 100m]                        ; prec_elegrad      ; precipitation gradient
0.2     ; [-]                               ; prec_summer_fact  ; factor for reducing precipitation correction during summer
*
* Melt
-0.6   ; [deg C / 100m]                     ; temp_elegrad      ; air temperature gradient
1.0     ; [mm w.e. C-1 d-1]                 ; melt_factor       ; melt factor for the DDF model
1.0     ; [10^-3 mm w.e. C-1 h-1 (W m-2)-1] ; rad_fact_ice      ; radiation factor ice
0.2    ; [10^-3 mm w.e. C-1 h-1 (W m-2)-1]  ; rad_fact_snow     ; radiation factor snow
*

```

Figure 10: example parameter file with all the parameters which can be set.