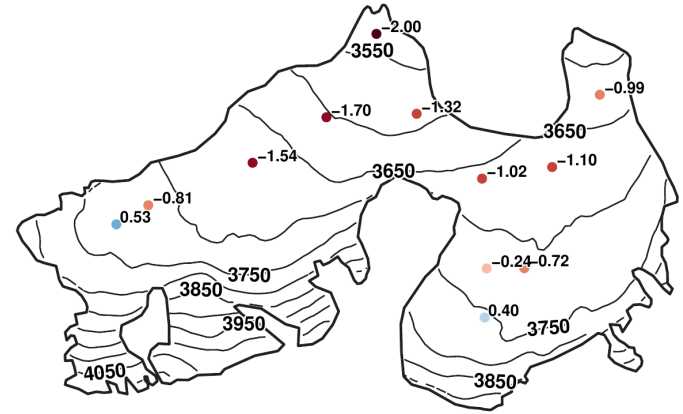


Modeling glacier mass balance from point measurements

Enrico Mattea

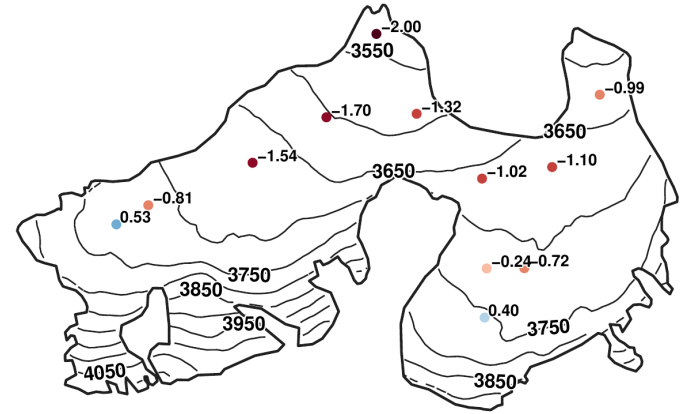
Introduction

- **Stakes and snow pits** are good measurements of mass balance, but **only at single points**



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- How do we go from these to the **total mass balance** of a glacier?

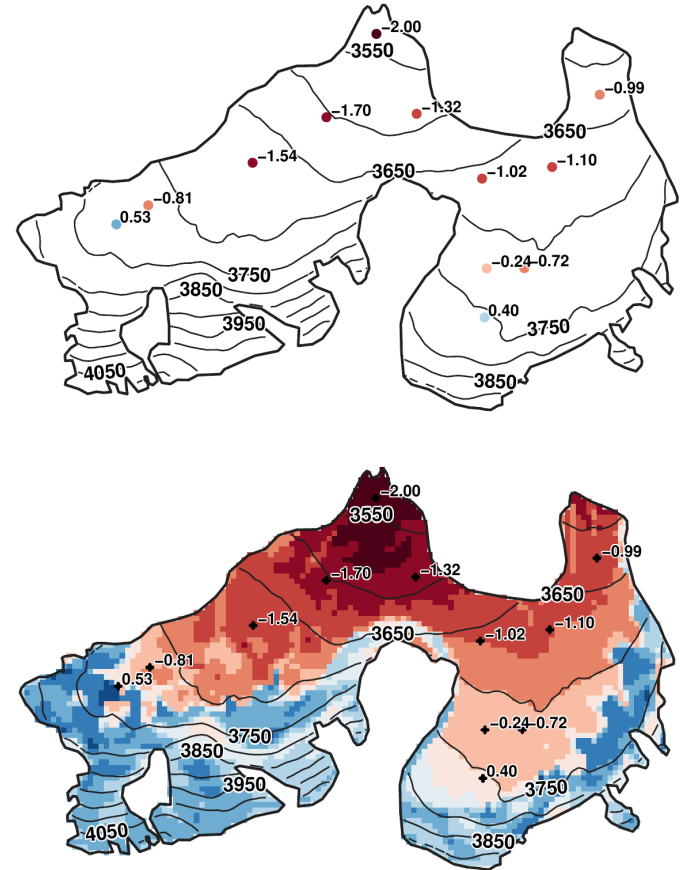


Introduction

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- How do we go from these to the **total mass balance** of a glacier?



Mass balance model



Mass balance model

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- **Accumulation** = Snowfall (rain/snow and total amount depend on altitude and topography)
- **Ablation** = Melt (depends on air temperature → altitude, but also on solar radiation → topography)
- **Avalanches** → Snow redistribution (also outside the glacier)



Mass balance model

- The model simulates **snowfall, melt and avalanches**

Mass balance model

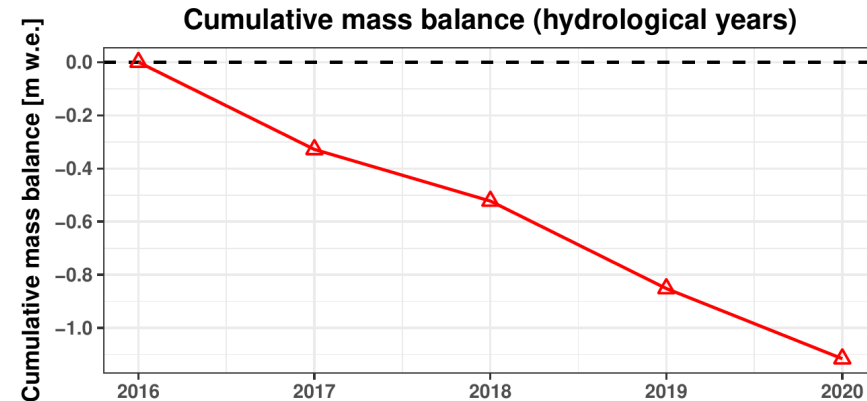
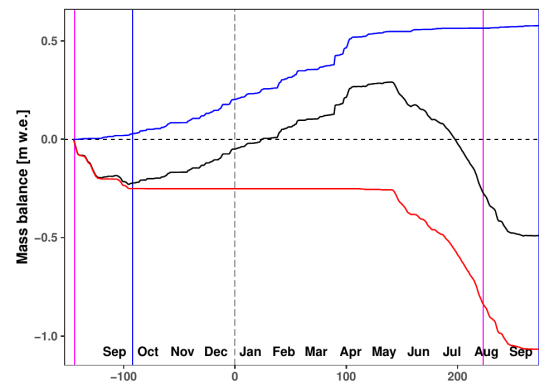
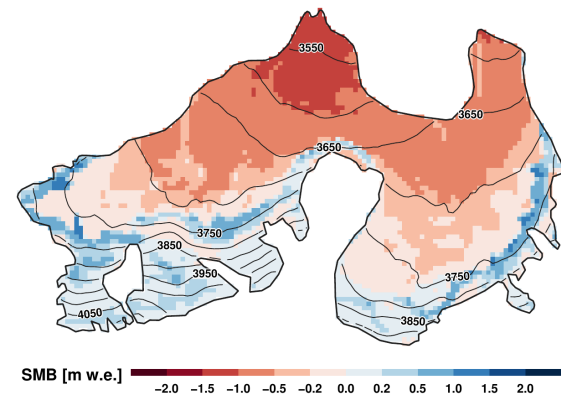
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Mass balance model

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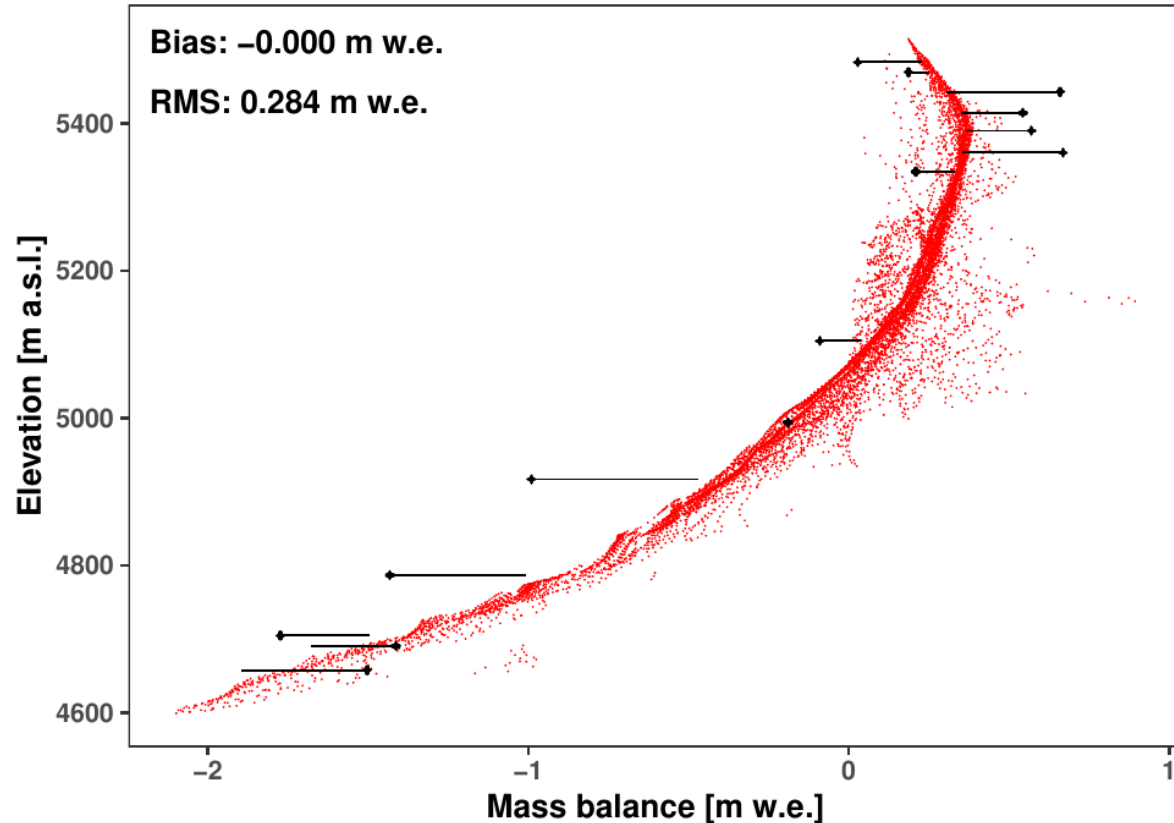
Mass balance model

- The model simulates **snowfall, melt and avalanches**
- On a **grid of cells** which cover the glacier
- At **daily resolution**
- **Output:** mass balance maps, time series, comparison with the measured points



Mass balance model


The simulation is automatically repeated to **optimize the melt parameters**, until there is no bias compared to the measured points




How to use the model

- The model uses the  script language: free, open-source

How to use the model

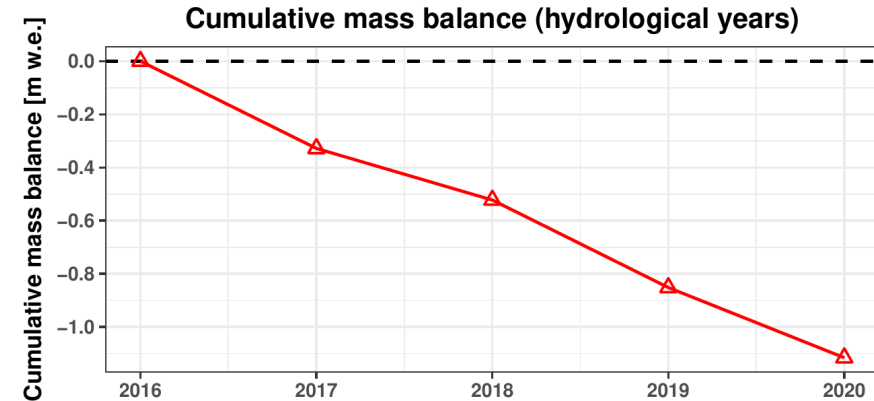
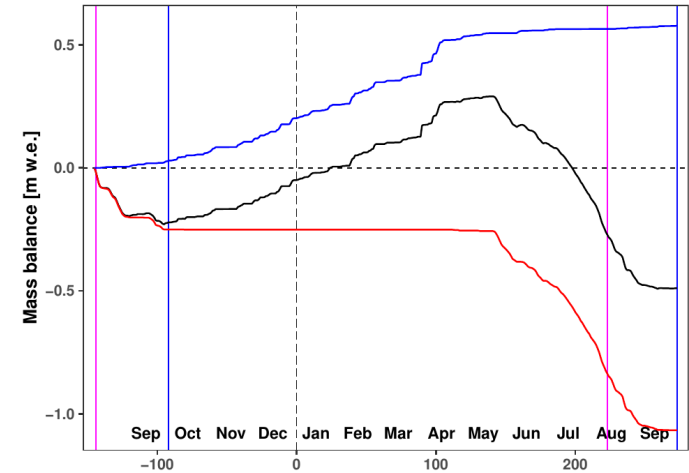
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How to use the model

- The model uses the  script language: free, open-source
- You have to **install some programs** to use the model: R, RTools, RStudio
- Installation is described in the **model tutorial 1**

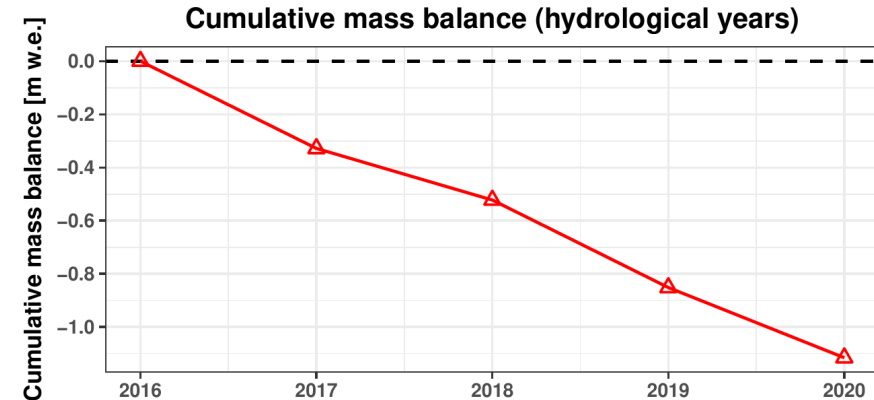
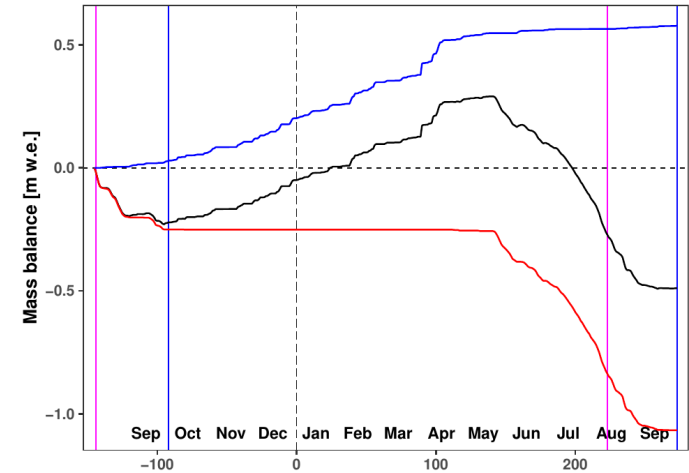
How to use the model

- The model can simulate one **single year** or **several years**



How to use the model

- The model can simulate one **single year** or **several years**
- For several years, the model also shows the **cumulative mass balance**



How to use the model

- Prepare the **input files**

How to use the model

- Prepare the **input files**
- Setup the model **parameters**

How to use the model

- Prepare the **input files**
- Setup the model **parameters**
- **Run** the model!

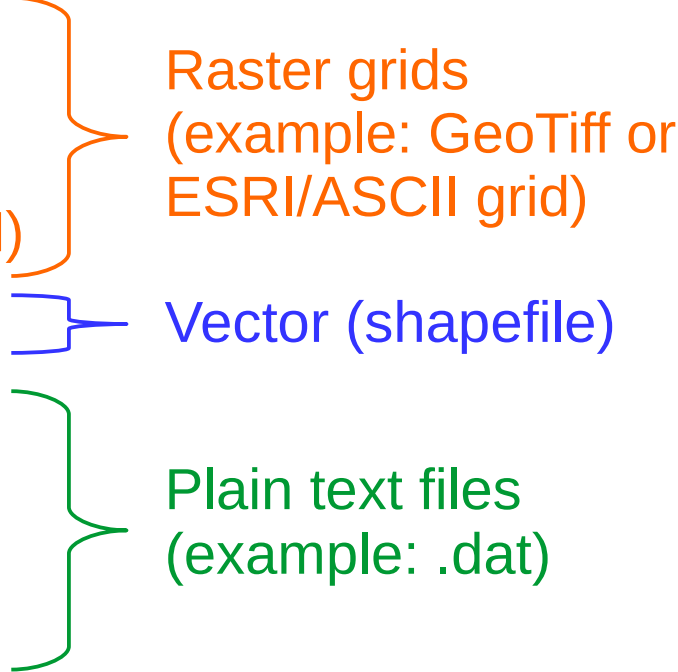
Input files

- Digital elevation model (DEM)
 - Surface type (ice, firn, debris)
 - Daily solar radiation (computed from the DEM)
- 
- Raster grids
(example: GeoTiff or
ESRI/ASCII grid)

Input files

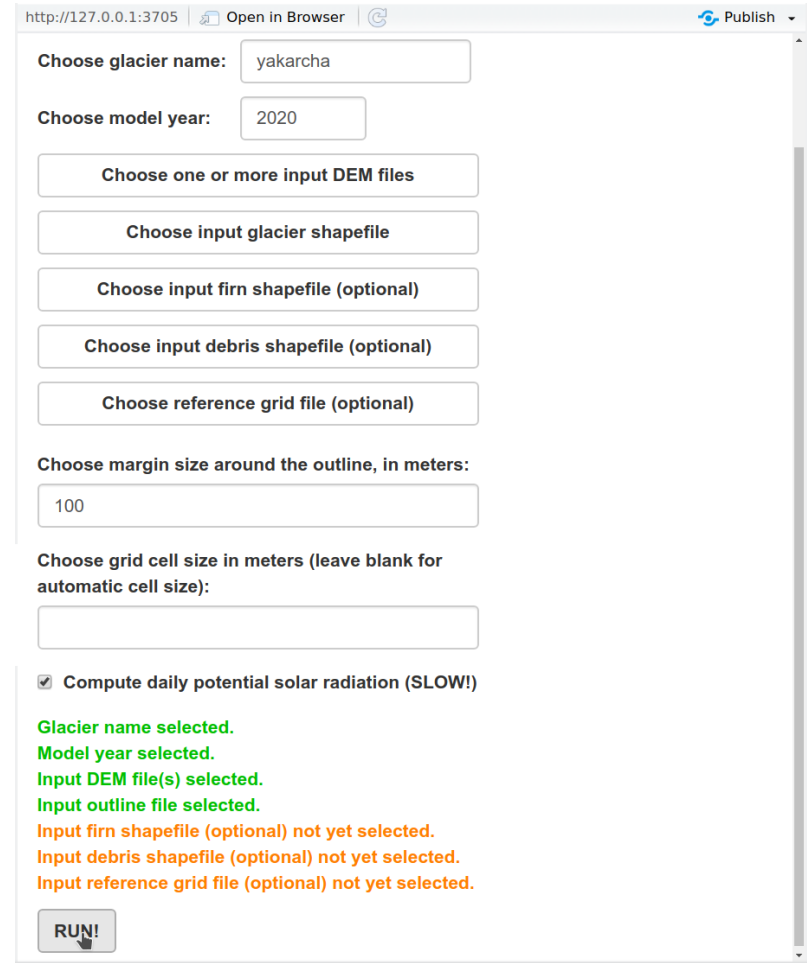
- Digital elevation model (DEM)
 - Surface type (ice, firn, debris)
 - Daily solar radiation (computed from the DEM)
 - Glacier outline
-
- Raster grids
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- Vector (shapefile)

Input files

- Digital elevation model (DEM)
 - Surface type (ice, firn, debris)
 - Daily solar radiation (computed from the DEM)
 - Glacier outline
 - Meteorological series (daily temperature and precipitation)
 - Mass balance measurements (stakes, snow pits, snow probes)
- 
- The diagram uses colored brackets to group the input files into three categories:
- Raster grids** (example: GeoTiff or ESRI/ASCII grid)
 - Digital elevation model (DEM)
 - Surface type (ice, firn, debris)
 - Daily solar radiation (computed from the DEM)
 - Vector (shapefile)**
 - Glacier outline
 - Plain text files** (example: .dat)
 - Meteorological series (daily temperature and precipitation)
 - Mass balance measurements (stakes, snow pits, snow probes)

Input files

- To prepare the input files: use the tool *make_input.R*



The screenshot shows a web browser window with a URL bar displaying 'http://127.0.0.1:3705'. The page contains a form for selecting input files for a glacier model. The form includes several input fields and buttons. The 'Choose glacier name' field contains 'yakarcha'. The 'Choose model year' field contains '2020'. There are five buttons for selecting files: 'Choose one or more input DEM files', 'Choose input glacier shapefile', 'Choose input firn shapefile (optional)', 'Choose input debris shapefile (optional)', and 'Choose reference grid file (optional)'. Below these buttons is a 'Choose margin size around the outline, in meters:' field with the value '100'. At the bottom, there is a 'Choose grid cell size in meters (leave blank for automatic cell size):' field. A checkbox labeled 'Compute daily potential solar radiation (SLOW!)' is checked. Below the checkbox, there are several status messages in green and orange text. At the very bottom, there is a 'RUN!' button.

http://127.0.0.1:3705 Open in Browser Publish

Choose glacier name: yakarcha

Choose model year: 2020

Choose one or more input DEM files

Choose input glacier shapefile

Choose input firn shapefile (optional)

Choose input debris shapefile (optional)

Choose reference grid file (optional)

Choose margin size around the outline, in meters:
100

Choose grid cell size in meters (leave blank for automatic cell size):

☒ Compute daily potential solar radiation (SLOW!)

Glacier name selected.
Model year selected.
Input DEM file(s) selected.
Input outline file selected.
Input firn shapefile (optional) not yet selected.
Input debris shapefile (optional) not yet selected.
Input reference grid file (optional) not yet selected.

RUN!

Input files

- To prepare the input files: use the tool *make_input.R*
- If you simulate **several years**, you can use several **DEMs**

The screenshot shows a web browser window with the URL `http://127.0.0.1:3705`. The interface includes several input fields and buttons for configuring a glacier simulation. The 'Choose glacier name' field contains 'yakarcha' and the 'Choose model year' field contains '2020'. Below these are five buttons for selecting input files: 'Choose one or more input DEM files', 'Choose input glacier shapefile', 'Choose input firn shapefile (optional)', 'Choose input debris shapefile (optional)', and 'Choose reference grid file (optional)'. A 'Choose margin size around the outline, in meters:' field contains '100'. A 'Choose grid cell size in meters (leave blank for automatic cell size):' field is empty. A checkbox labeled 'Compute daily potential solar radiation (SLOW!)' is checked. Below these are several status messages in green and orange text, indicating which parameters have been selected. At the bottom is a 'RUN!' button with a mouse cursor icon.

http://127.0.0.1:3705 Open in Browser Publish

Choose glacier name: yakarcha

Choose model year: 2020

Choose one or more input DEM files

Choose input glacier shapefile

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RUN!

Model parameters

- Two types of parameters: **fixed parameters** and **annual parameters**

Model parameters

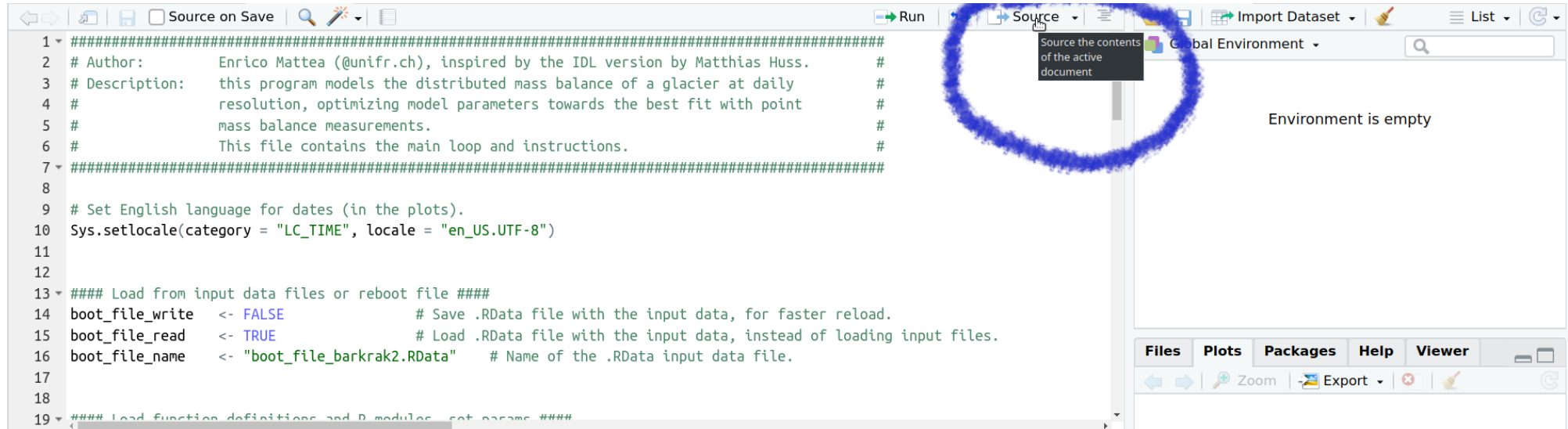
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Model parameters

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- **Fixed parameters:** glacier name, model years, AWS altitude, physical parameters (snowfall distribution, avalanches, ...)
- **Annual parameters (optional):** to use a special value of a parameter in a specific year. One file per year (example: *param_2020.dat*). Precipitation correction, melt factors, altitude bands for contour-line correction.

Running the model

- When input data and parameters are ready:



Running the model

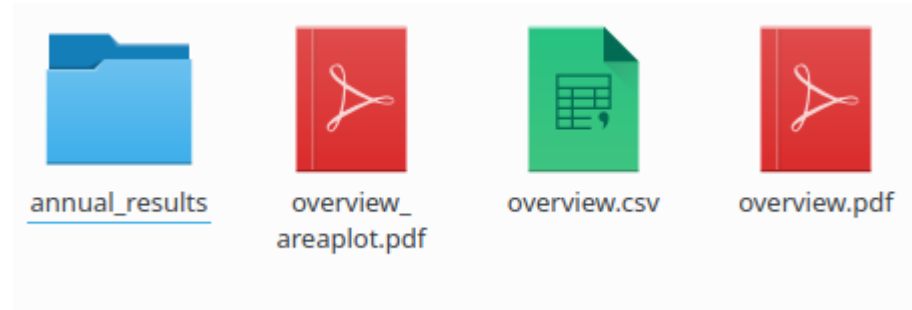
- Model output:
 - **PDF** files → plots
 - **CSV** files → data of the plots
 - **TIF** files → GeoTiffs (for QGIS or ArcGIS)

Running the model

- Model output:
 - **PDF** files → plots
 - **CSV** files → data of the plots
 - **TIF** files → GeoTiffs (for QGIS or ArcGIS)
- Output files:
 - *overview.pdf* → main results
 - *overview_areaplot.pdf* → mass balance 1 Oct to 30 Sep
 - *annual_results/* → detailed annual results

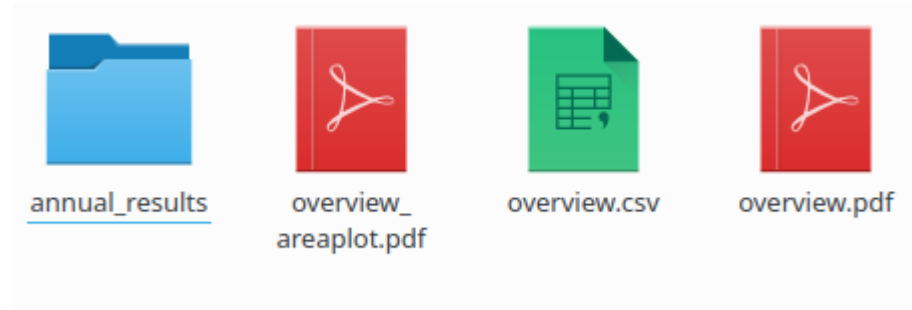
Running the model

- Main output files:

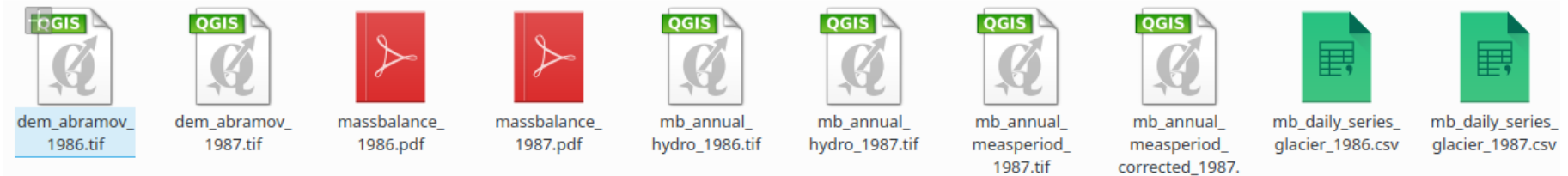
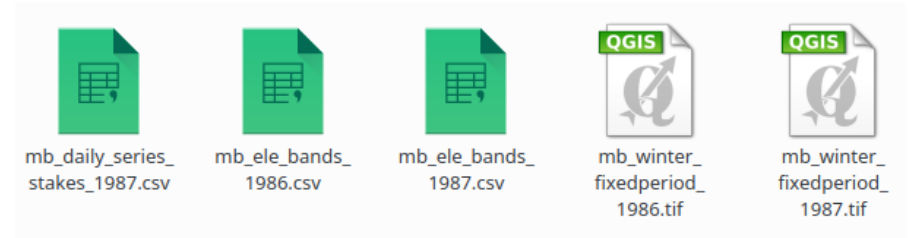


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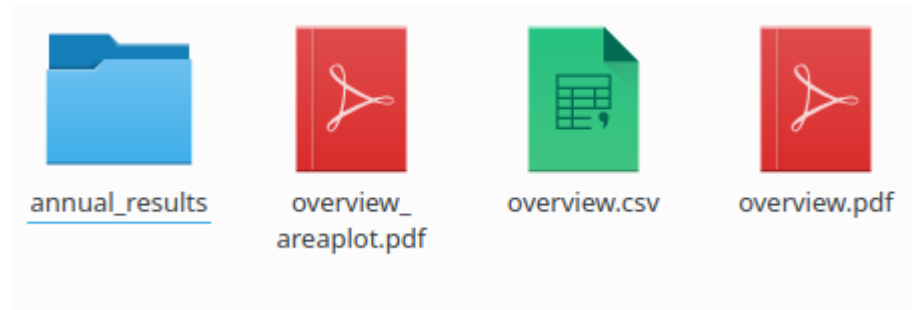


- Under *annual_results/*:

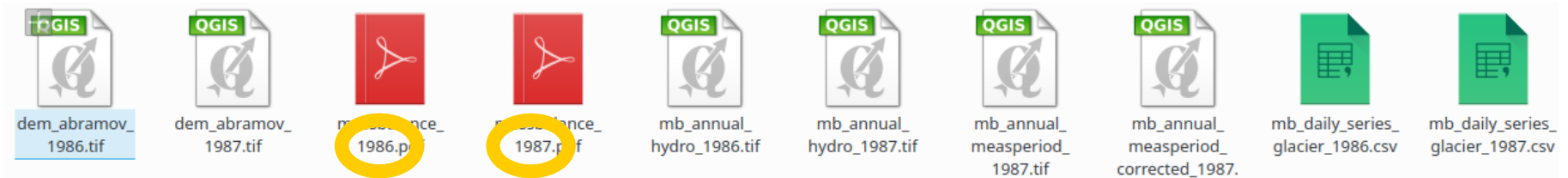
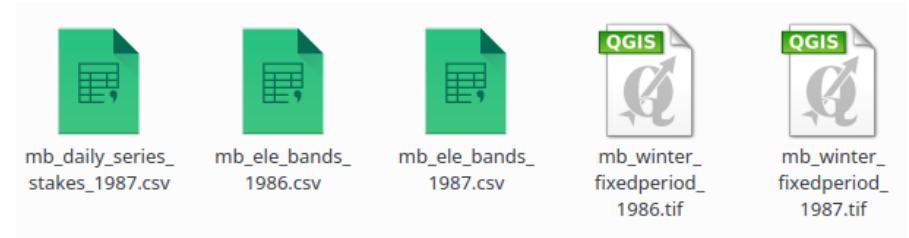


Running the model

- Main output files:



- Under *annual_results/*:



An aerial photograph of a massive glacier flowing through a mountain valley. The glacier is a mix of white and grey, with visible longitudinal stripes of moraine material. It is flanked by steep, rocky mountain slopes. In the background, more snow-capped peaks are visible under a clear blue sky.

Thank you for your attention!

enrico.mattea@unifr.ch