Glacier mass balance distributions in the french Alps from 1996 to 2010, based on a regionalisation of ground measurements

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AIM AND SCOPE

Glacier volume changes computed from direct mass balance measurements are performed worldwide on a limited number of mountain glaciers, within a very unequal spatial distribution. Furthermore, even in regions with a developed monitoring network such as the french Alps, field measurements in this region only cover about 13% of the total glacial area.
The present work aims at producing quantitative information for the 87% unmonitored glacier cover.

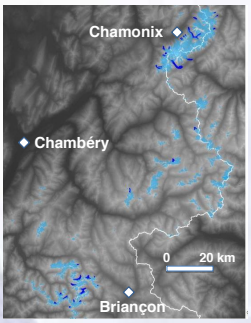

Figure 1: Glacierized areas in the french Alps. Dark blue represents debris-covered ice and light blue represents clean ice.

MASS BALANCE DATA

➢ 82 yearly mass balance series from point measurements over the 1996-2010 period from the monitored glaciers of the GLACIOCLIM observatory, plus one glacier of «Parc National des Ecrins» (Gl. Blanc).

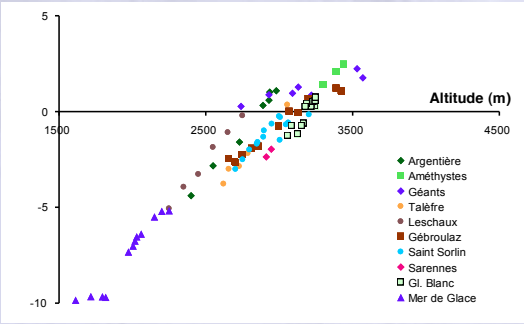

Figure 2: Point measurements of the 1996-2010 glacier mass balance plotted as a function of elevation. Colors indicate the different glaciers.

DATA ANALYSES

A sensitivity analysis of the 82 series to elevation, aspect and latitude was conducted. Figure 2 shows the dependency of mass balance to elevation.
With an average correlation coefficient of **0.96**, elevation (Z) is the primary variable explaining the mass-balance distribution. With coefficients of **-0.36** and **-0.27**, the relation with the cosine of aspect (A) and the latitude (Y coordinate), respectively, are less strong, but still significant to the 0,1% and 2% level.

MASS BALANCE PARAMETERIZATION

A multiple regression equation was then established for each one of the 15 years of the data set :

$$\text{Mass balance} = a \,.\, Z + b \,.\, \cos(A) + c \,.\, Y + d$$

(average multiple regression coefficient: 0.98)
The 15 equations are the basis for the yearly parameterization from 1996 to 2010. The original data set does not include debris-covered areas, or elevations above 3500 m a. s. l. The debris-covered areas (5% of the whole domain) were hence excluded from the regionalisations. In order to keep the mass-balance within realistic values at high elevations, it was limited to a maximum of 4 m. That value is reached only in the highest parts of Mont Blanc, mostly above 4000 m.

PARAMETERIZATION INPUT DATA

➢ SRTM digital terrain model at 90-m pixel size.
➢ Glacier outlines from a glacier inventory realized using 2003 satellite images for the french glaciers, plus outlines provided by E. Motta (Fondatione Montagna Sicura) for 2 Italian glaciers.

ACKNOWLEDGEMENTS

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G. Consoli (vacataire LGGE, Fr) made the first mass balance calculations with a GIS.

YEARLY MASS BALANCE DISTRIBUTION

The parameterizations were used to compute annual mass balance distribution over the whole domain, using the QGIS geographical information system. Glacier extent is constrained by the 2003 inventory outline. The result is a 90-m mass balance distribution grid for french and bordering glaciers of Switzerland and Italy (Figure 3).

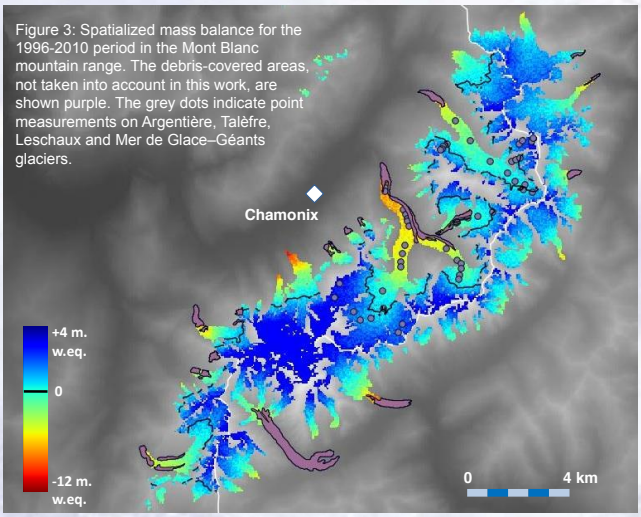

Figure 3: Spatialized mass balance for the 1996-2010 period in the Mont Blanc mountain range. The debris-covered areas, not taken into account in this work, are shown purple. The grey dots indicate point measurements on Argentière, Talèfre, Leschaux and Mer de Glace–Géants glaciers.

RESULTS

Mass balance series of individual glaciers, as well as for larger areas can be extracted from the yearly mass-balance regionalisations. Examples of results are shown in figure 4. The modelled mass balance series of Glacier d'Argentière in the North of the domain shows a good correlation with the measurements (r=0.96), as for Glacier Blanc (not shown, r=0.97) in the South. The mass balance for the whole domain, i.e. french Alps and bordering glaciers, is less negative because large glaciers with developped ablation tongues are much less frequent than small glaciers.

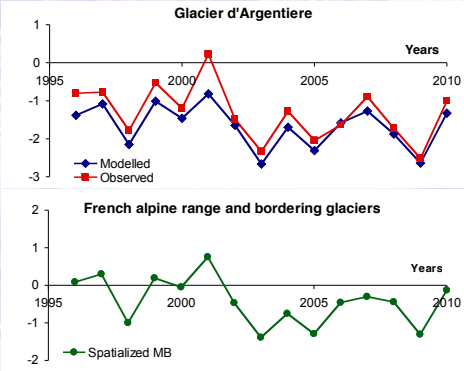

Figure 4: Upper panel: compaison between modelled and measured mass balances time series for Glacier d'Argentière. Lower panel: global mass balance of the whole domain.

CONCLUSION

With the same parameterizations for the whole domain of study, the model is able to reproduce mass balance series of very different glaciers such as Glacier Blanc and Glacier Argentière, at the extreme ends of the domain, with different aspects and altitude ranges. The model is an efficient tool for providing mass balance variations of unmonitored glacier or global variations in the French Alps.

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