Detecting glacier-bed overdeepenings for glaciers in the Western Italian Alps using the GlabTop2 model: the test site of the Rutor Glacier, Aosta Valley

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FOREWORD

It is expected that the rapid retreat of glaciers will continue in the future. One of the most evident and relevant consequence is the formation of new glacier lakes in recently deglaciated areas. During glacier retreat overdeepened parts of the glacier bed become exposed and, in some cases, filled with water.
It is important to understand where these new lakes can appear because of the associated potential risks (i.e. lake outburst and consequent flood) and opportunities (tourism, hydroelectricity, water reservoir, etc.) especially in densely populated areas such as the European Alps.

THE TEST SITE

The **Rutor Glacier** (8,1 km^2) is located in the Aosta Valley (Graian Alps, Italy).
After the last advance occurred during the 70s of the previous century, glacier shrinkage has been continuous and new lakes have formed in newly exposed overdeepenings.

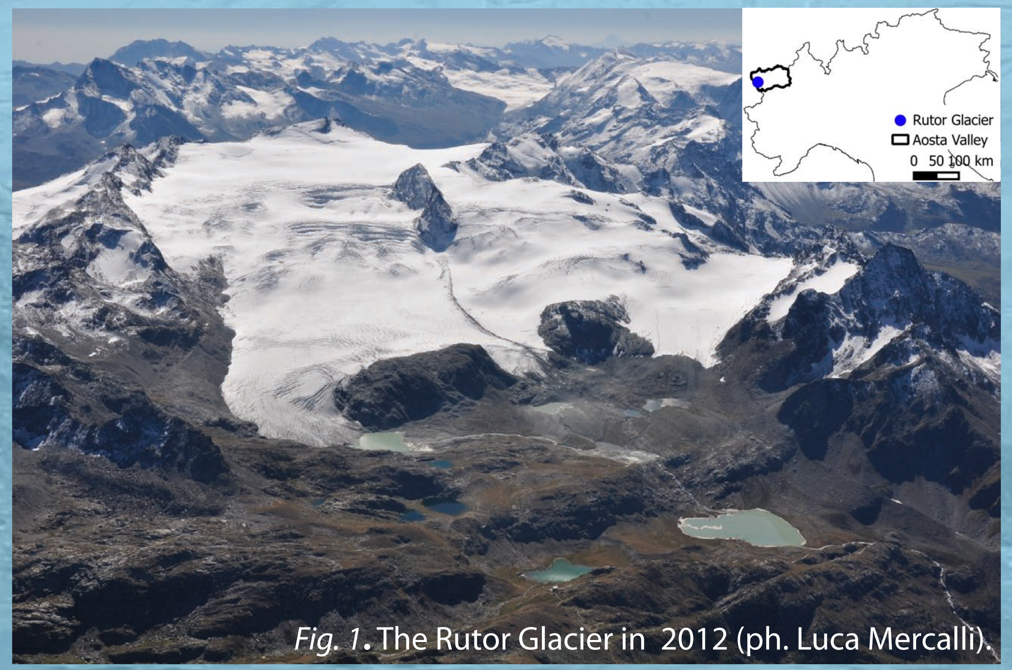

Fig. 1. The Rutor Glacier in 2012 (ph. Luca Mercalli).

GLABTOP2

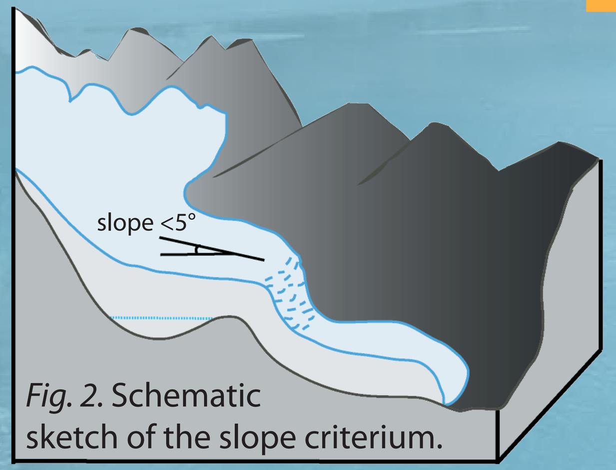

Fig. 2. Schematic sketch of the slope criterium.

The glacier surface is a smoothed image of the underlying bed. Mean slope is a basic parameter that influences glacier thickness (fig. 2): the steeper the glacier, the thinner the ice and vice versa (Linsbauer et al., 2009).

GlabTop2 (Glacier Bed Topography model version 2) allows to model **glacier bed topography** over large glaciated areas combining digital terrain information and **slope-related estimates of glacier thickness** (Linsabauer et al., 2016).

Ice thickness is calculated for an automated selection of randomly picked DEM cells (auburn cells) within the glaciarized area (fig. 3).
The calculation requires estimating the parameters τ (basal shear stress) and the shape factor *f*.
In the present work we set τ=100 kPa and *f*=0.9.
The resulting ice thickness distribution provide the bed topography.

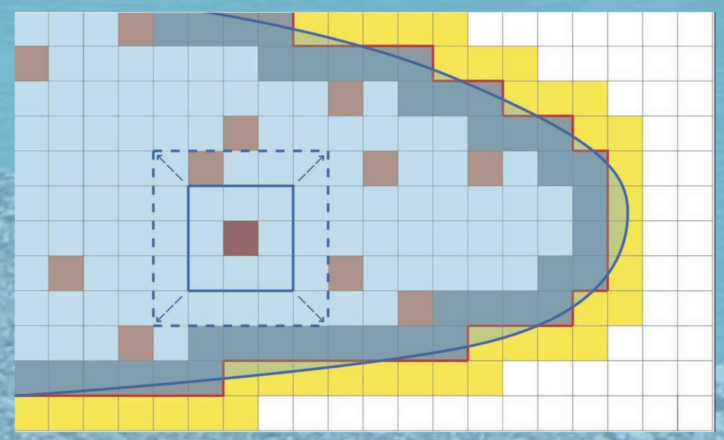

Fig. 3. Schematic illustration of GlabTop2 (Frey et al., 2014).

DATA AND METHODS

The model requires a minimum set of input data: **glaciers outlines** and a surface digital elevation model (**DEM**).

We applied GlabTop2 to:
1) DEM derived from historical data (aerial photos stereo pair) representing conditions before the proglacial lake formation. The results obtained have been compared with the present situation and existing lakes (see results and discussion).
We performed the triangulation (RMSE$_{xy}$ 3 m; RMSE$_z$ 5,5 m) and we extracted the DEM, than we orthorectified the two aerial photos (n. 5118-5119) of the **1954 GAI flight** using the LPS software. We manually digitized the glacier outline in 1954 (fig.4).

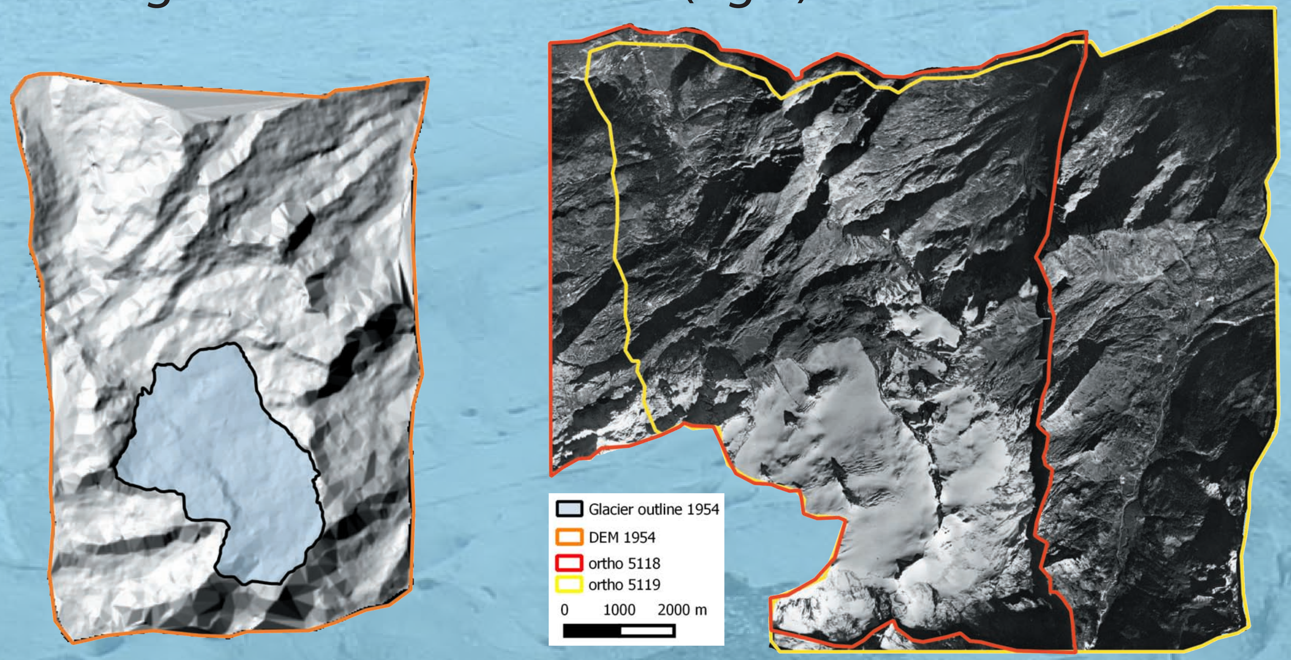

Fig. 4. DEM and orthophotos by 1954 photo pair elaboration.

2) Aosta Valley Region official **DEM (1991)**, in order to model future overdeepenings and verify their location and shape through GPR data.

RESULTS

1) Comparison between modelled overdeepenings (fig. 5) and existing lakes in the proglacial area (fig. 6) shows correspondence in their location.

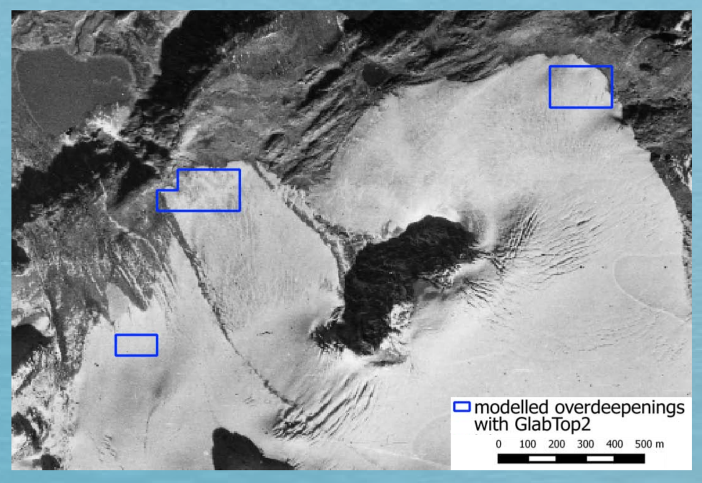

Fig. 5. Modelled overdeepenigs by 1954 DEM.

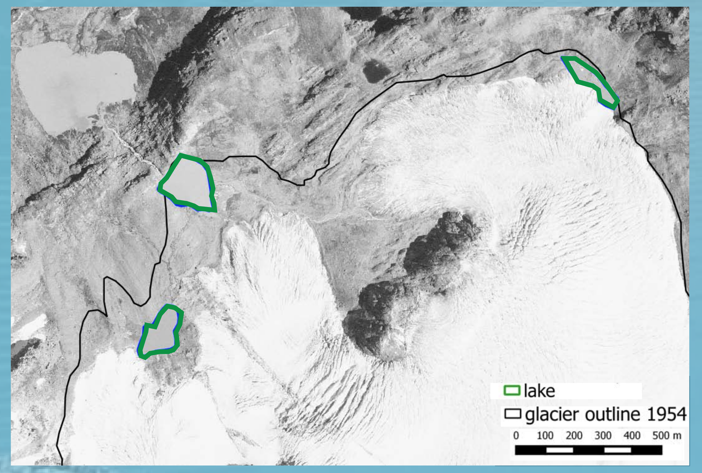

Fig. 6. Proglacial area in 1988 with existing lakes.

2) The larger modelled features probably reflect real bed overdeepenings, these correspond well with areas were glacier surface slope is <5° (fig.7).

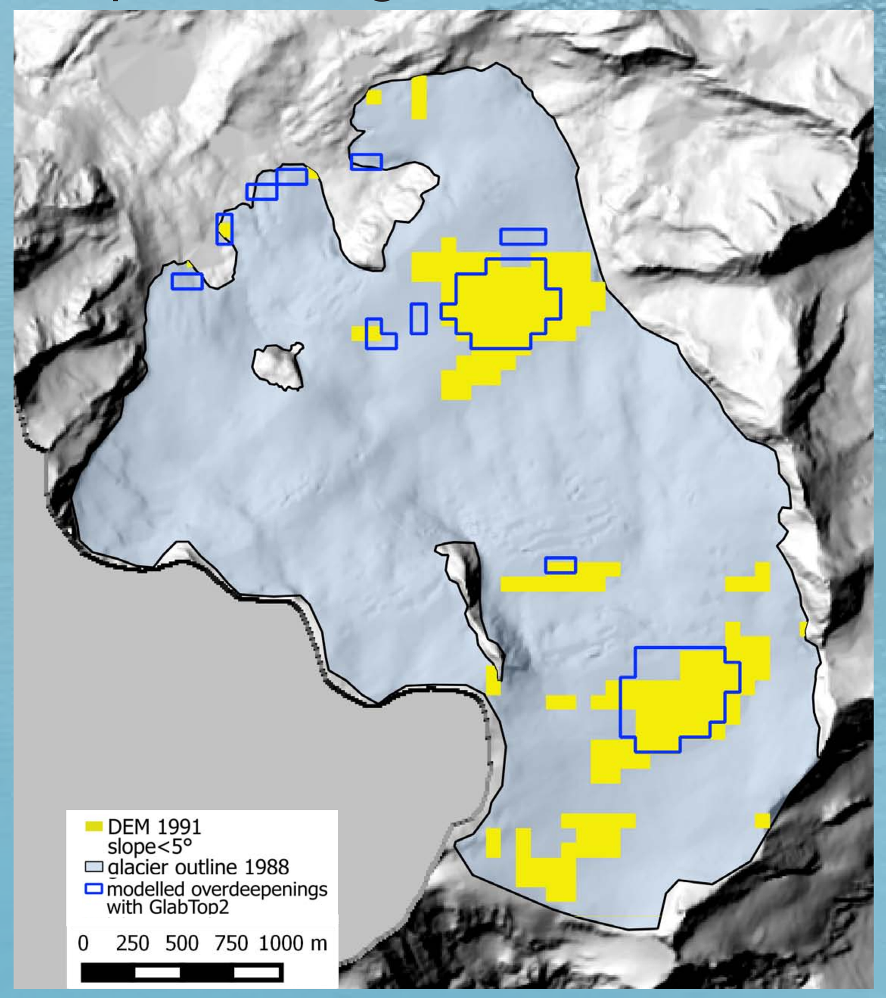

Fig. 7. Modelled overdeepenigs by 1991 DEM.

DISCUSSION

1) We compared results of GlabTop2 with the "without glacier" situation represented by the1991 DEM in the proglacial zone through AA' and BB' profiles (fig. 8).
The comparison reveals that GlabTop2 generally models the parabolic shape of glacier bed in good agreement with the real shape of the proglacial area (fig. 9a).

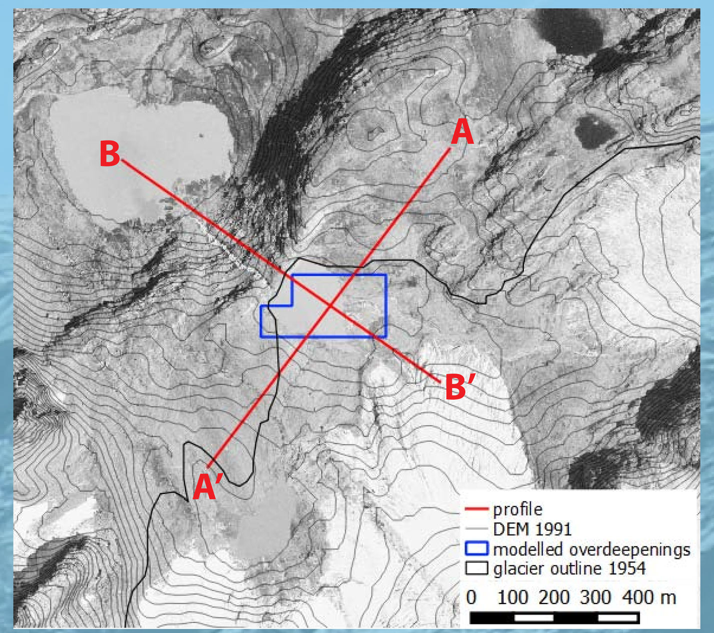

Fig. 8. The AA' and BB' profiles are shown in red.

The model results generally capture well the geometries of the overdeepening (fig. 9b). Data from 1991 DEM often show higher elevations but within or close to the uncertainty range.

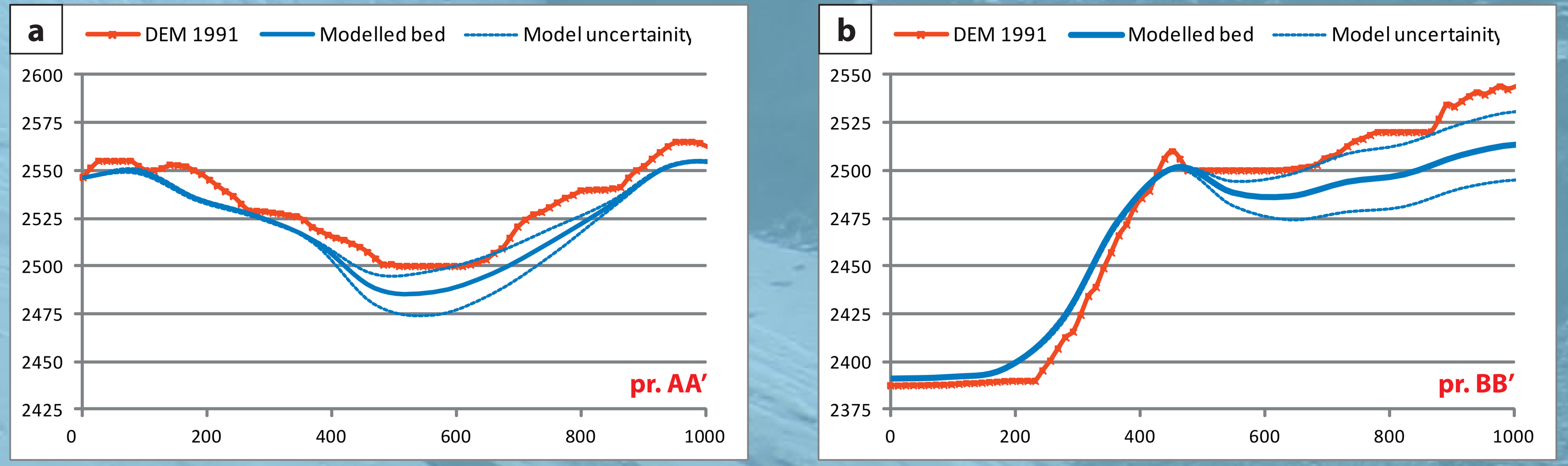

Fig. 9. Comparison of data from1991 DEM with modelled bed through AA' (a) and BB' (b) profile in the proglacial area. Graphics show: elevation versus distance as modeled by GlabTop2 (blue line), a +/-30% uncertainity range (blue dotted line) and the present-day topography of the proglacial zone (red line).

2) We are performing preliminary comparison of the model results with GPR data from different surveys (ARPA, 2013; Villa et al., 2008): modelled ice thickness (about 100 m in the deepest area) is in agreement with thickness measured by heliborne GPR.

CONCLUSION AND FUTURE PERSPECTIVES

Preliminary results confirm the robustness of GlabTop2 in detecting the overdeepenings and their location.

Based on the results obtained with model application and verification at Rutor Glacier, GlapTop2 will be applied over larger areas of the Western Italian Alps (Piemonte and Aosta Valley). Locations of possible future lakes will be assessed to facilitate identification of potentially hazardous conditions and dynamics.

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