

Review of manuscript tc-2011-89

„Glacier ice in rock glaciers: a case study in the Vanoise Massive, Northern French Alps“ by S. Monnier et al.

This manuscript investigates the formation and origin of the Sachette rock glacier, Vanoise Massive, French Alps by combining ELA reconstruction, aerial photogrammetry and an advanced analysis of GPR measurements. My expertise is on ground-penetrating radar but I am not a glaciologist and not a geomorphologist. Hence, my comments primarily focus on the GPR part of the paper. For the other methods and geomorphological/glaciological interpretation please refer to the comments of the other two reviewers.

The study uses two CMP gathers along with two longitudinal and two transversal GPR profiles measured along the Sachette rock glacier in order to determine its internal velocity structure and stratigraphy. The CMP measurements are evaluated with standard methods leading to velocities for the upper part of the rock glacier indicating its high ice content. For the longitudinal transects, reflection hyperbolas are evaluated and interpolated in order to create 2D velocity profiles along the rock glacier. In addition, all GPR profiles are topographically migrated with an advanced method (Lehmann and Green, 2000) providing detailed information about the complicated internal structure of the glacier. Initially defined morphological sections along the glacier are discussed along with the estimated velocity structure and the migrated radargrams to explain the internal structure of the Sachette rock glacier. Overall, the paper is well written and well structured and the figures support the content of the paper. I have a few comments regarding the analysis of the GPR data which I would like to have worked out before publication of the paper. A major focus should be placed on comments 1 and 4 (see below).

Comments related to GPR:

1. P. 3605, L. 4...P. 3606, L. 5: From the given information it is difficult to judge the success of the hyperbola fitting and interpolation procedure as the results will strongly depend on the distribution and quality of the hyperbolas along the transects - information which is not shown so far. Please add a figure showing the non-migrated radargram and indicate the hyperbolas that were used for the evaluation. It might be that the radargram is too long to resolve all the hyperbolas. Then an additional cutout from the radargram showing a representative distribution of features over the complete depth range could solve this issue.
2. P. 3607, Section 4.3: Please relate these results to those derived from the analysis of the lateral profiles. This should at least be possible for transect L#2 where the CMP position is very close to the measurement line.
3. P. 3608, L. 9...12: This could also be caused by a larger uncertainty in velocity estimation due to rather flat-shaped hyperbolas at this depth; remove „small“ in L. 11.
4. P. 3608, L.24.25: How can a change in velocity be determined without data? Please do not show velocities in Figs. 7 and 8 for sections that are not confirmed by measurements.
5. Section 4.5: In this section, the authors compare the stratigraphic information from the migrated radargrams with the morphological divisions and the estimated 2D velocity images for transect L#1 and L#2. Comparing the structural information from the migrated radargrams with the 2D velocity profiles, I would have expected more consistency between the still rather smooth velocity structure and the very dynamic stratigraphic structure revealed by the migrated radargram. For the first 100 m of both longitudinal radargrams, the velocity structure nicely follows the shape of the basal reflector. Further downslope,

the velocity profile is often oriented perpendicularly to the structures imaged in the radargram. Reflections are caused by changes in permittivity (= velocity), hence they should somehow correspond to each other. What is the process making the velocities cut the stratigraphic structures? This requires a more detailed discussion.

Specific and technical comments related to complete paper:

P 3598, L. 14: significance with respect to what? Please specify.

P. 3599, L. 9: please correct: morphologically

P. 3599, L. 18: Humlum (2000) missing in reference list

P. 3599, L. 26: again: significance with respect to what?

P. 3601, L. 17: please correct: „...on *it's* western flank...“

P. 3603, L. 15: please add reference to Fig. 5

P. 3604, L. 6: please add „... and lateral margins of the glacier.“

P. 3604, L. 14: Here I would prefer „components“

P. 3604, L. 23: Here I would prefer „volumetric liquid water content“ to separate it from the permittivity of glacier ice which is almost the other extreme.

P. 3605, L. 6: please correct „...by the GPR software...“ and add reference for the software (I guess it is Sensors and Software (2003) as provided in the reference list)

P. 3605, L. 20: I am not sure if I get the context correctly. If the sentence starting with „We especially...“ refers to the analysis introduced right before, I suggest to replace „We especially used...“ by „This consisted of using...“ to clarify the context.

P. 3612, L. 13: Please provide a number for the dielectric permittivity of permafrost material.

P. 3613, L. 26: Please replace „challenge“ by „challenges“.

Figure 2: The figures and labels are way too small to be read in detail. Please make sure that they are large enough in the final version of the paper.

Figure 7, 8 and new, unmigrated figure: Please indicate the position of the CMP measurement on transect LP#2.

All Figures: Please make sure that labels are large enough.

Reference:

Lehmann, F. and Green, A.: Topographic migration of georadar data: implications for acquisition and processing, *Geophysics*, 65, 836–848, 2000.