Lake ice thickness variability obtained from ground penetrating radar measurements

Kai Rasmus
Department of Geophysics
P.O.Box 64 (Nils Hasselblomin katu 2)
FIN-00014 University of Helsinki
FINLAND

e-mail: Kai.Rasmus@Helsinki.Fi

Introduction

The classical way of measuring lake ice thickness is by drilling one or two holes. This method assumes a totally homogeneous lake ice cover, which is of course very rarely the case. Only by drilling tens of holes, which is time-consuming work, can anything be said about the thickness distribution. Ground penetrating radar is both faster, and the spatial resolution obtained this way is much better than what is achievable with the classical method. The radar also has the capability of showing the pattern of the undersurface of the ice and periodic features can be seen. It is almost impossible to get detailed information of the variation in the undersurface of the ice just by drilling.

This study looks at the lake ice thickness distribution as seen by ground penetrating radar. The experiment was made on a small mountain lake in the Tarfala valley in northern Sweden in April 2001.

Ground penetrating radar

For an in depth discussion into the workings of a ground penetrating radar and especially its use in the study of the cryosphere, the reader is referred to Gruber and Ludwig (1996). In this report we intend to just state the main formulae required to understand this work.

The velocity of a radar wave inside a medium is:

$$v = \frac{c}{\sqrt{\varepsilon}} \qquad (1)$$

where c is the speed of light in that medium and ε is the permittivity of that medium. When we know the velocity and the two-travel time, τ, of the radar wave through a layer back to the antenna, we can calculate the layer thickness. This is simply:

$$d = \tfrac{1}{2} v t = \frac{c t}{2\sqrt{\varepsilon}} \qquad (2)$$

Scattering of electromagnetic wave, of which radar waves are composed, are reflected from permittivity gradients. This means that it is possible to detect the snow/ice and ice/water interfaces on lakes because all of these media have different permitivities.

Measurements

Measurements of the lake ice thickness distribution were made in the Tarfala valley (67° 55’N 18° 36’E) in northern Sweden in April 2001. The measurements were made at the end of the winter season when the ice was at its thickest and before it had started to melt.

The radar used was a Ramac radar operating at a frequency of 800MHz. It was pulled onto the lake ice from the shore. It was setup to fire a pulse into the ground every 20cm. The radar was pulled by hand and the triggering was done automatically using a trigger string that was attached to a pole at the beginning of the transect.

Fig. 1 shows part of the lake ice radar track. The snow / ice interface and the bottom of the ice can be clearly seen. The different layers were identified manually and analysed using the radar data analysis program Haescan. The results are tabulated in Appendix 1.

The depth of the ice layer was calculated from the two-way travel times using equation (2) with a velocity value of 0.16 m/ns for ice.

Results

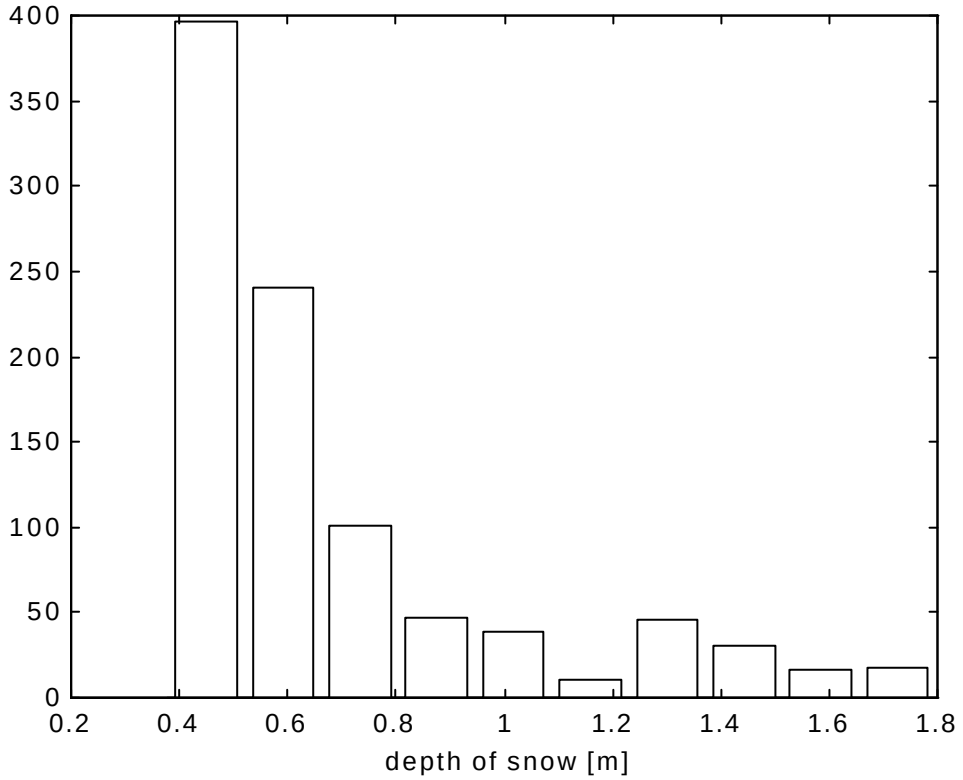

Fig 2. The histogram of the depth of the snow cover.

Histograms of the measurement results are shown in Fig. 2 for the two-way travel time in the snowcover above the ice and in Fig. 3 for the depth of the ice. It can be seen from the figures that the snow depths are are skewed towards the smaller snow depths. The ice depths are almost normally distributed with a slight skew towards the larger depths. The mean value of the snow depth is 51cm and the mean depth of the ice is 75cm. The standard deviations are 8cm and 13cm for the snow and ice respectively.

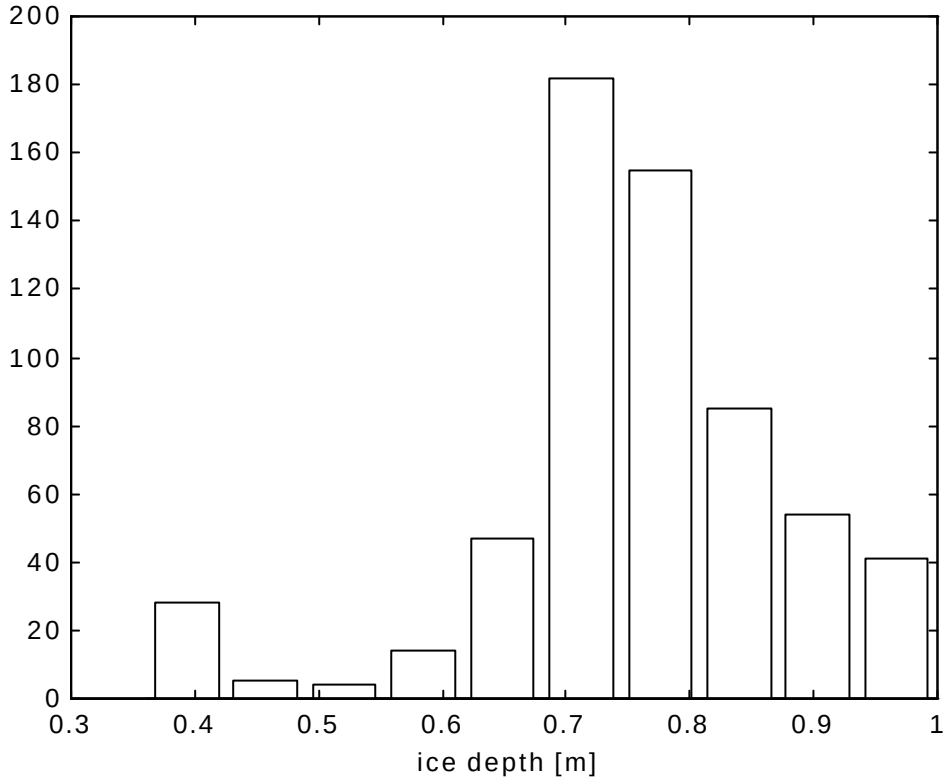

Fig 3. Histogram of ice depth values. It is slightly skewed to towards the higher values with a second maximum at the very small values.

Conclusions

The thickness distribution of lake ice in a lake in northern Sweden was studied using ground penetrating radar. It was seen that this method brings up the distribution reasonably well. The data show that simply by drilling in one location, it is impossible to get a truly accurate knowledge of the lake ice thickness.

It was found that the thickness was almost normally distributed. The overlying snow however was distributed totally differently.

References

Gruber, S. and F. Ludwig, 1996, application of ground penetrating radar in glaciology and permafrost prospecting, Arctic Centre, University of Lapland

Appendix 1

Analysed radar two-way travel time data for the lake ice transect.