Ground penetrating radar (GPR) - and how to get results that are useful

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Abstract

The purpose of the following experiment is to compare a GPR profile with actual snow and ice thicknesses along a track. In addition the radar ray velocity in the snow and ice were calculated and compared to the normal velocity for the layers.

Two profiles were made but only one could be used to calculate the velocity in snow and ice. We found the velocity in the snow to be 224 m/μs compared to the normal 220 m/μs. The velocity of the lake ice were found to 165 m/μs compared to the normal 168-170 m/μs. The difference can be due to that the normal values are from glacier ice and the values we calculated were from lake ice.

The difficulties to make the best measurements will also be discussed in the rapport.

Figure 1: The people that carried out the GPR measurements. From the left: Kai, Gro (myself), Yvonne and Kai. John took the picture.

Introduction

During the week at Tarfala Research station near Kebnekaise in the Northern Sweden we learnt about the use of Ground Penetrating Radar (GPR) to make radar profiles. The profiles show different areas and how the bedrock underneath the glacier is behaving - if there are mountains, hills or other lithologic stuff that have an influence of how the glaziers is moving.

The most important in this experiment seems to be 'learning by doing' while we found a lot of errors afterwards. This rapport will give a view of how we did, what we did wrong and what will be good having in mind when doing the experiment in the future.

The GPR measurements where done by John, Kai, Tore, Yvonne and myself (Figure 1). We needed to be so many people because there had been a tremendous amount of precipitation in form of snow. This made it a bit difficult getting around with the radar. But we managed to make two profiles. One along some stakes and one from the end of the stakeline and out on the lake at the end of the valley.

The profiles that were made and that there is referred to in this paper, can be seen at the homepage: www.urova.fi/home/hkunta/jmoore/glacioleurolab2/glacioeurolab2data.html under 'Radar data pcx image files' profile number 3 and 4.

Theory

Before starting measuring with the GPR you have to know what you want to look at. The different frequencies of the radar penetrate different depths of the snow and ice. A radar with high frequency can not penetrate so deep and shows details better than a radar with a low frequency.

If you want to look at the snow in a valley or look at the depth of the firn layer on the polar ice you have to use a radar with high frequency. If your interest is in finding out whether mountains or hills underneath the ice sheet or icecap have an influence of the flow in the ice you need a radar with a low frequency. The great depth that low frequency radar gives will not show details in the same amount as the high frequency shows, but it will be possible to se internal structures in the ice. Internal structures such as where there is warm ice, cold ice and maybe identify layers with great extend.

Radar frequencies that are used to penetrate up to 200 meter depth can for example be a 200 MHz radar which has a resolution of about 0.8 meter. If you use a 800 MHz radar the penetration is much less and so is the resolution, that is around 0.2 meter.

The radars do not take into account any elevation differences that might occur along the track. So it is best to use them in a flat area to get a realistic idea of how the internal layers and the bedrock are.

The measurements

The radar is dragged over the area that is going to be searched. The radar can either be shielded or not (figure 2). If the radar is shielded it means that the electric pulses are only send in a known direction - here downwards - where unshielded radars will send the electric pulses in all directions both up and down.

The radar consists of a device that makes electrical pulses (radio waves) of a certain frequency and a receiver that registers the reflection time. Through a computer the data is converted into an image.

The electrical pulses reflect on boundaries with different impedance change. The impedance is frequency dependant – which depends of permittivity and conductivity in the layers.

Permittive layers will create a difference in the velocity of the radio waves. Conductive layers will not be reflected because there is no water and thereby no movement is possible in the layer. The change in permittivity determines how much of the radio wave that is reflected upward and how much continues down into the layers underneath.

Like any other kind of measurements on the nature there can be errors in the data. Internal errors in the ice can be dust and aerosol, which have an influence of the reflection from the radar. But also external errors can happen. If electrical or other magnetic matters are close to the radar there can be an error in the data. If the influence is constant it is possible to correct the data.

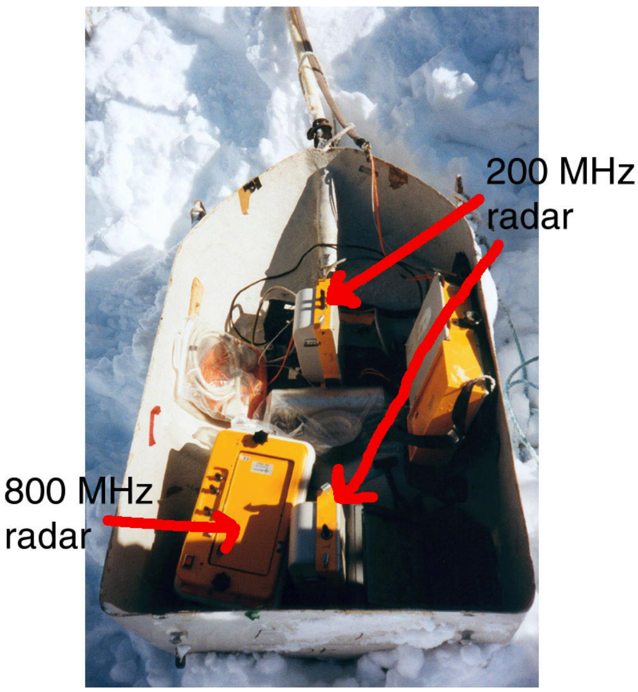

Figure 2: The glass fiber sledge in which the radar was carried. On the picture it is possible to see both radars - the 200 MHz that consists of two unshielded parts and the shielded 800 MHz radar that only consist of one part.

Setup of the computer

It is needed to set some parameters in the computer program that is used for the measurements so that the data can be made into an image. You need to know what maximum depth you want to look at and from that calculate the parameters.

To get the time for the samples you divide the depth you want to look at with the normal velocity of the subject. The sample frequency (fs) is 6 to 10 times the depth. The last parameter that is needed to be known is the time window which is found by dividing the number of samples (Ns) that is collected with the sample frequency (fs).

In the setup of the computer program you choose if the radar sends the electrical signal at a certain time or if you tricker the signal by yourself at a certain distance. The time tricker can be useful when making measurements on an icecap dragging the radar by scooter at a constant velocity. The string tricker is good when you have to drag the radar yourself and it is thereby possible to stop for breaks without thinking of the radar measuring the same spot several times.

The results

One experiment was made along the stakeline located from the research station and one kilometer up the valley. Another profile was made from the end of the stakeline and out on the lake where an ice core was drilled.

Two persons dragged the shielded 800 MHz radar in a sealed fibre glass sledge. One carried the computer and the tricker line and marked the stakes on the profile. That is all that is needed for the experiment - but because of a thick layer of soft snow two persons made tracks in front of those who carried out the measurements.

The profile shows that the bedrock surface varied in elevation. The profile shows that the depth of the snow column changes along the track. Whether the measurements are in two-way time or not is not known, but when calculating on the results it is assumed that it is two-way time.

- along the stakeline

This profile can not tell anything because there are so many errors in the measurements. Two times the string that triggered the radar to send out the radio waves was triggered by false reasons. The first time the string took an end and was replaced by a new. Where it is seen on the profile I'm not sure. The second time was when a snow scooter drew into it. The string did not break, but it made the radar measure a couple of times at the same place. This can be seen on the profile at about 280-290 m.

The profile can not be used because of the many errors tied to the measurements. The markers that were supposed to show where the stakes were located along the line were also made when the 'computer person' did not push the button to make the markers (why is not known!). Then it was thought that if we knew the exact location of the stakes - measured by GPS - it would be possible to calculate the distance between the stakes. And by these calculations it would be possible to find out, which markers on the radar image that were the correct ones. But GPS data were only recorded for the first couple of stakes.

Another error is, that the snow depth measured with the snow probe was not made on the same day that the radar profile was made and it was not measured in the track where the profile was made. Therefore it was not possible to calculate anything from this profile.

- out on the lake

We made another profile. This one was started where the other profile ended and went out on the lake that is located at the end of the valley. We were going to meet another group of people here that was going to make an ice core.

This profile is much more fun to look at compared to that from the stake line. Around 80 meters from the start it is possible to see two major reflections - they are marked at the profile picture.

The reflection that can be followed from the start of the profile, is from the boundary between the snow and the lake ice. The other reflection is showing the boundary between the ice and the water. An echo of this reflection can be seen two times below the ice-water boundary.

Close to where the lake profile ends an ice core were drilled. The exact location is not known, but the radar profile shows that the thicknesses of the snow and the ice are almost uniform. Because of the measurements from the drilling site it was possible to use this profile to se how the velocity is in the two elements.

The snow layer was approximately 56 cm thick and the ice core that was drilled was 76 cm long. From knowing this and looking at the two-way time on the profile the velocity can be calculated. The two-way time that is used is a mean value from the area between 200 meter and the end of the profile.

The length of the core in meter is divided by the one-way time in nano-seconds times 10^3.

The velocity in the ice was calculated to be 165 m/μs from an average two-way time of 9,2 ns and a length of ice on 76 cm. This is very close to the normal velocity for ice that is between 168-170 m/μs. The difference can be due to the air bubbles and water that is found in lake ice. These things slow down the velocity.

The velocity of the snow was calculated to be 224 m/μs from an average two way time of 5 ns and a depth of snow of 56 cm. The typical value is around 220 m/μs. The small difference can be because of the light snow that is on the lake.

These results make it possible that the drilling site is very close to the 220 m.

Conclusion

How to make the perfect GPR measurements is not so complicated. The greatest error that we made was because of the difference in place and time for measuring the snow depth.

To obtain the best results you have to know the exact location of the profile and measure the snow depth in the same track as the profile is made. The best way of measuring the snow depth with a snow probe would be to measure in some known positions (measured with a GPS) right after the GPR has been measured, so that it is possible to compare the actual snow or ice depth with the profile from the radar.

The results that were calculated from the lake profile is good. The velocities lie close to the normal velocities of the layer. But not knowing the exact location is not good.