Calculating the Depth of Polar Ice using Radar

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1 Introduction

In this activity, you will learn how researchers measure the depth of polar ice as it relates to studies of climate change. The speed of light is normally a constant,

$$c = 3.0 \times 10^8 \ \ m/s \tag{1}$$

That is, a wave of light (like a radio wave) travels 300 million meters per second in a vacuum. However, in a material such as ice, the speed is

$$v = \frac{c}{n} \tag{2}$$

In Eq. 2, the variable n is called the *index of refraction.* In general, it varies according to the frequency of the radio wave or wave of light. At radio frequencies, the value is $n = 1.78$. Suppose a radio wave is shot downwards through ice, reflects off of the ocean below, and returns to the receiver. If the ice thickness is h, then the total distance traveled by the radio wave will be $2h$. In general, if Δy is the total distance traveled, v is the speed, and Δt is the time, then

$$\Delta y = v\Delta t \tag{3}$$

Speed is just the ratio of distance and time. Let's assume that $\Delta y = 2h$, and $v = c/n$. This implies that

$$2h = \frac{c}{n}\Delta t \tag{4}$$

Suppose we measure Δt and we assume $n = 1.78$. The measured ice thickness would be given by

$$h = \frac{c\Delta t}{2n} \tag{5}$$

2 Examples

Derive the ice thicknesses below:

1. Suppose we observe $\Delta t = 4.0$ μs. One μs is equal to 10^{-6} seconds. What is h?
2. Suppose we arrive at a place in the Antarctic where we observe $\Delta t = 6.1$ μs. The next year, we observe $\Delta t = 6.02$ μs. By how much did the ice thickness decrease?

3 The Open Polar Server

On the classroom PCs, go to the following website: `https://ops.cresis.ku.edu`. Click on the tab in the upper left labeled **Antarctic**. This should take you to a map of Antarctica, containing flight lines of aircraft collecting radar data over the ice sheets.

1. Click on one flight line and pull up a radar "echogram." The y-axis represents Δt, and the x-axis represents distance or location. The coler scale of the diagram represents the power P of the radar returned signal.
2. On the right-hand y-axis of these diagrams we see the time delay in μs. Identify the surface of the ice, and identify the bottom. Estimate the times in μs.
3. Calculate the depth of the ice sheet along the flight line in five different places.