WHAT'S BELOW THE SURFACE?

Using advanced mathematical methods, high-powered electromagnets and helicopters, we push the boundaries of groundwater mapping.

The different layers of soil, clay and sand that lie below the surface of the ground might seem irrelevant to you unless you are interested in geology. However, the fact is that knowledge of these layers plays an important role in our daily lives. When we open the tap to have a drink of water, we expect water to come out and we expect it to be clean. Such high quality is only possible because we have accurate knowledge of the location of our groundwater resources, how the water flows in the subsurface and where it is vulnerable to pollution.

A simple and very accurate way of finding out what lies in the subsurface is to simply drill a very deep hole and look at what comes up. As you can probably imagine, drilling to a depth of 500 meters takes time, and if you want to map a large area with many closely spaced drill holes, you quickly run out of time and money. This is where geophysics comes into play with some alternatives to drilling.

How can we then gather information about the subsurface without drilling? To explain the method, let's do a small experiment of thought. Imagine three identically shaped bells; one in silver, one in iron and lastly one that is cast with a layer of silver and a layer of iron. If you hit each imaginative bell, they will ring with different sounds, and with a little practice you would probably be able to tell the bells from each other by their ringing sound. Just like the third bell, the subsurface consists of layers of different materials. We can try to hit the earth's surface and measure the resulting vibrations, but this will not tell us much unless we hit with the power of a small earthquake. Instead, a much more practical method is to "hit" the earth with a powerful magnetic field, generated by an electromagnet. This magnetic field will make each of the subsurface layers give off its own, much weaker, magnetic field and the sum of these weak fields can then be measured. This is what is known as the Transient Electromagnetic Method or just TEM.

In practice, the electromagnet is lifted by a helicopter and flown over the survey area, at approximately 80 km/h at an altitude of 50 meters. Once you have a set of TEM measurements, they can be converted to a 2D or 3D map of the subsurface through a complicated mathematical process called inversion. Unfortunately, any imperfections in the measurements result in inaccurate maps. Things, such as radio signals, lightning strikes across the globe, vibrations in the TEM system hanging below the helicopter and radiated signals from power lines result in such imperfections which we call noise. Additionally, due to some practical and physical limitations in the design of the system, the measurements are distorted. In the analogy of the bells, the situation is like trying to distinguish the sound of a silver bell from an iron bell, both situated behind a wall in the next room, while your friends are having a conversation behind you.

My project is part of a larger groundwater mapping project involving the Hydrogeophysics Group at Aarhus University, who are among the leaders in converting TEM measurements to subsurface maps, and the Aarhus based company SkyTEM, who are world leading in TEM equipment for groundwater exploration and conducting groundwater surveys. My niche is between these two. New developments in the SkyTEM system makes it possible to apply digital signal processing methods to improve the quality of the measured responses as much as possible before they are processed further.

The goal of my project is come up with mathematical methods that remove the noise and repair the distorted measurements in order to make sure that we utilize all the information that is hidden within the measurements. The hope is that we will be able to gain more precise knowledge of the subsurface than currently possible, and utilize this knowledge to locate and secure groundwater resources worldwide.

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