

Topic 2c (part 1) - Finding detail in the snow-pack - snow density and snow profiles

When we look at the snow cover from the outside or from above, snow cover just looks white. But within the snow cover, there is a multiple of information buried down. Usually they have to make big holes, shovel the snow out, and then measure all these layers.

But the institute in Davos developed a new instrument called SnowMicroPen, which is actually a device here showed. It is a pen that is driven into the snow very slowly, and the pressure at the very top of this needle is recorded very accurately. And that's how we can see all the density difference within the snow that was shown here.

You can see the person has to lean on the instrument because the snow layers are quite hard. When you look at the snow measurement here, this is the snow density in the red measured with the micro snow instrument, MicroPen, at very high resolution.

This is the density, 400 kilograms per cubic metre. That is the depths, 50, 100, 150 centimetres at just the very top. And in black line, you can see every five centimetre the density was measured.

It is what we call a Kelly Cutter. We cut out the piece of snow. We weigh on the balance, and we take the average. So you can see the difference in information is that one needle going through, and we did not even have to take out the snow, so it's a new method to measure the snow density.

Why is that important? First, we want to know what is the amount of snow that has fallen throughout the winter that will be melted away during the summer and this is called ablation. When you reduce the snow cover and then start to melt, we ablate, we melt the snow.

We also melt partly the ice. And that density is true at one location, but it varies actually over a distance. And that's why when you want to investigate how variable is your snow density, or 40 metres means you have to make 40 snow pits, that there's two, three days of work.

All you have is snow. This instrument that drives down, and you move every few metres or every few centimetres and that gives you this kind of a display. In light colours, you see the very hard layers. So these are wind crusts created by the wind throughout the winter, because this is accumulation from one winter about 125 centimetres.

And then you have ice snow that is much lighter and that's usually just above the ice surface. We call it the hoar frost. So this is the reason why we want to know density to calculate how much water actually melts away, how much ablation we have.

There are other ways to look at the density variation. That is just another location. That is at Summit, and everything is quite smooth. It looks very similar.

And now we installed also radars. A radar is an instrument that sends out a pulse and it measures the return. Quite easily seen here, these are two radar antennas. One sends out the pulse, and the other antenna receives the return from these different layers.

So we can continuously measure the snow cover above a radar, how it actually increases when we have snow, how it decreases when we have melt. We installed two of these snow radars in Greenland, one at Swiss Camp. And because Swiss Camp, we have at the lower part ice, we had to invert the radar, so we're looking down.

At Summit, the highest point in Greenland, we put it underneath the snow. And I show an example of data that was used in Switzerland. We don't have the latest result yet from Greenland, but it's the same. It's a snow cover that is falling throughout the year and then melting.

And we have three instruments you can see here. This is the snow, how it builds up, 0-25. That's the time, nanoseconds here. It's given in snow height. So we have 2.5 metres of snow in the Swiss Alps that build up throughout the winter, stay level, and then melt.

This is from December 1st, the 1st of July. This is now the analysis of the entire data. We can run it through. And you will see in the following here is a time series, the return from the radar.

In this image, you see the surface covered, because the snow appears, and disappears, and this stick gives you an indication where the snow height is at that very moment. Let's try to get this animation going. And you can see now how the snow builds up, how the surface change.

And you can see here where the snow is quick increase, decrease from a snowfall from a wind blown event. And that gives us an entire annual record of snowfall, but also it gives us internal layers. You can see these black lines.

These are layers we can follow throughout a whole winter season and that is used in our ice snow models, how the snow cover builds up, disappears, and this is actually what we call ablation. We have a snow increase that is accumulation.

We have a winter. It's cold. Nothing happens. Redistribution and then the snow disappears, and that's the ablation of the snow cover.

Snow is very complex and has a really broad range of structures. Let's think about satellites and how the signals the satellites receive, where do they come from? It's sometimes a huge mass.

It's area sometimes of several square kilometres where a satellite receives a single signal like a pixel. Now how do we deal with this complexity then in calibrating and validating the satellite images? What's clear, we can't sample millions of small snow samples.

So we have to invent other methods. And one method is that we make a fast vertical profile, this very high vertical resolution. Let's say if it's a SnowMicroPen, traditionally we did a snow pit that took us an hour, and then we had to measure, try to classify the layers, and then we had a problem because when you do two pits and two observers, do they classify the layers the same?

Maybe, maybe not, and that's where the near infrared photography comes in. Snow is white and that's a problem for normal photography. And in the near infrared, we can see layers, which we can't see just by naked eye or a normal camera.

From the measurement of the SnowMicroPen that we are doing in the field, we can reconstruct such a figure. On this picture, we see the stratigraphy of the snowpack, for alpine snowpack for this one. And what we can see is the beginning of the season in December until March, so we start with a snowpack of 30 centimetres, and we arrive at something about two metre.

So every day we did the measurement with the SnowMicroPen, which probe into the snowpack, and will give the hardness of the layers that are encountered when they go down. So you can see the evolution over the entire season.

The blue colour was in the fresh snow, while the red colour are more like the dense and packed snow. So here, because we did this daily measurement, we can really track the layer over time. So for instance, here you can see this layer of densification, or here you see the crust that passes during the whole season.

Sometimes we don't have the whole season, but we only have for one day. And then we have, for instance, the stratigraphy of the snowpack at one point, at one moment of the time, so, for instance here. So it reveal about the stratigraphy of the snowpack, how is it layered.

So for instance here, you go from the top, which going to be fresh, and when you go down here, you see one dense of layer, then again less dense, and so on. What is important is that each layer, because it's dense, because the structure of the snow is different, we'll have a behaviour that is different in term of optic, or mechanics, and so on.

These are measurement that we do in the ground in situ. And this kind of data can be used to validate the data that are simulated by models. So of course you cannot be always outside, and doing the measurements that we have modelled that simulate the stratigraphy of the snowpack, and we can use such data to evaluate and confront to the model.

So here we see the evolution of the density of the snow over time. So the blue represent the light snow, the fresh snow, and the red represent the denser snow. And what we can see here is, for instance, this snowfall becomes this layer here, and you see that it goes from blue colours to red colours, so you see the densification of the layer over time.

The layer densifies with time mainly because after when there is a new layer on top, that make weight, and then it's just because of the weight on top, the snow will rearrange and densify.

This is the evolution of the stratigraphy of the snowpack, also an example from Alpine snowpack. But what is interesting to see, so here we dig snow pit into the snowpack, so vertical hole, and we take a picture with near infrared filter, which highlight the stratigraphy of the snowpack.

So, for instance, because people sometimes think that snowpack is homogeneous, but actually it's really layered. So here you can see, for instance, here is a really small 1cm layer. Here you see another one and so on.

The stratigraphy of the snowpack really depend on the condition that the snow is submitted to. So, for instance, this ice crust, it was a melt event early in the season. This kind of large structure of grain is when the snow pack is submitted to a large temperature gradient, to wind, or temperature, or solar radiation will affect the stratigraphy, and this will stay over the whole season.