Ice Monitoring from Space - Introduction

- It has now been over 40 years I have gone to the Arctic on an annual basis for expeditions. For the last 25 years, I have studied on the Greenland ice sheet. First, processes. I want to understand how much energy is absorbed on the ice sheet, how much is reflected. But if you lean back and look, all the measurements we have and this is a good example, 1992 to present, that was the graph we used for the the IPCC report. We summarised all the satellite measurements. What ice loss can be retrieved from all the papers. Let's look at the total picture.

This is actually now the Greenland ice sheet here in Greenland. That was the curve I just showed you. This is Antartica, responding in a very similar way. The time scale is the same, 1992 to present and these are all the glaciers worldwide. So the glaciers are actually losing twice as much ice than Antartica and Greenland. But we do know there is only about 50 cm sea level left in all the glaciers when they melt. So it is important, but within the next 50 years we will lose half of the glaciers worldwide. By the end of the century, we probably will have lost 80%. That means we know how much is left. The big question is the ice sheets. How are they responding? The global sea level change we observe today is not caused only by melting ice masses. It is actually a complex picture, if you see here are the ice shelves contributing water to the ocean. It is also that the ocean is warming up, so a warmer ocean has a bigger volume, so about 1/3 of the signal is actually by warming the ocean, because it absorbs the heat from the atmosphere, or it does change if you take water out of the ground. So if you pump too much water out, the landmass locally will actually subside, so it changes the coastline. And there are others, but more importantly there's a combination.

Currently, ice sheets and the glaciers are the biggest factor affecting sea level. And here I can give you some examples. If you look at one of these lakes in more detail, you can see there is some water running away. And that's one of the key. The water fills up in the basin and runs out and then falls into what we call a "moulin". A moulin is a vertical shaft that the water penetrates and this has become one of the key issues. This water pushes underneath the Greenland ice sheet. And for a certain time, during the big melt events, it can reduce the friction underneath. So the ice can flow faster, and you can see this is what the moulin looks like. This is 120 metres, but water is coming at different levels into that moulin. That means the water from all these lakes are connecting in these big tubes, over 10 metres wide, over 100 metres deep, then horizontally and the water penetrates through, or stores in here, and warms the ice sheet. Warm ice moves faster. And that's what we see in all these satellite measurements. The ice, towards the margin, is doubling in speed, all around Greenland. Part of it is the warming up of the ice through this, and therefore combining field observation with satellite is needed to explain the change and to take that change for the models into the future. During summer when you spend some time on the Greenland ice sheet, making measurements, sometimes you come in areas, it sounds like a train is riding through. It's a thunder. But you actually hear is big water channels, rivers falling 100 metres straight into the ice sheet. This is very loud, and we know we are losing, every year now, in Greenland alone, 250 gigatonnes of ice. Let's compare that volume. It's hard to imagine how big it is. But those who actually know the Alps in Europe, all the Alps in Europe have 60 gigatonnes of ice. So we are losing four to five times the volume of all the glaciers in Europe, every year, by additional melt. And that thunders into the Greenland ice sheet, makes enormous noise, so we actually had a camp close by, we had to move away. It was too loud. It was like camping at the train station in central Europe somewhere. These moulins are not just happening in one place. Every half a kilometre is another moulin. So it's a network of these moulins and that has increased, we can see that from satellite imagery, by counting the moulins we can see that, by the surface deflating, because it's melting down, and we can see that by the increase of fresh water that is pushed into the ocean, because the ocean has a salinity. It gets diluted by fresh water, which changes circulation, which changes the fish stock, and it changes the entire environment along the coast as well.

When we make these observations, it's important to understand the process but equally important is, we continue to observe the same area over time. Because if you just come one year here, these moulins stand here, the next year the ice has moved away. We have to measure five, 10, 20 years depending on the variables we measured. We are running these models that gives you the feedback here. This is the Greenland ice sheet, the lower part. And in blue you see no temperature change, or zero. When we increase the melting, what we have seen through these channels, which is evident, we know that it's actually increasing the temperature inside the Greenland ice sheet. What you see here is just the difference between the long-term mean we had until 1990, and putting the additional melt into the model we know from our measurements, from the satellite, it's up to eight degrees, getting warmer inside Greenland. And you would say, "So what?" But eight degree warmer ice is much more flexible. You can move it faster, and that is one of the reasons the ice moves faster towards the coast. And we know from all the satellite data ice along Greenland is accelerating towards the coast. One of the effects is given here. But let's look at the longer-term feedbacks.

Greenland is so heavy, it pushes the land masses below sea level. And what you can see the blue areas here are below sea level. If I remove the entire ice, you can actually see Greenland is an island below sea level. It is blue in the centre, that means these are canyons up to a kilometre below sea level and this is the feedback that becomes important to study. If the ice is retreating, what we can see now from the measurements and from the observation, the water can penetrate into the inner part and it actually melts much more efficiently from underneath. The air can only melt one, two, three metres of ice because the air needs to warm up the ice. If the ocean water is underneath the ice, you can melt 50 to 100 metres of ice per year, easily. So 10 times, 20 times more ice loss by water that is eroding ice from underneath. And you can see we have one, two, three, four big gates, we call them, underneath Greenland. So we might watch and see in the next 10, 20 years, how quick is it moving. Now this is only possible through satellites. We cannot have that many grad students sitting here and making observations. We need the satellite like GRACE, the Gravity Climate Satellite that looks at the entire mass, changes in mass. Or we need Cryoset, that gets that very accurate elevation, and at the end I can actually show the summary of Cryoset and other satellites. How do we see the Greenland change? And you will see the Greenland here color-coded in red. When it's red, over time, you lose more ice. And this is actually given in metres. And you can see we are losing ice all around the perimeter, that means the lower area. Because the ice is flowing faster, because the ice is melting faster. But we only know that because we make long-term observations. And this is the long-term observation from satellite, given from 1992 to 2012, from all satellite combined. And it shows us very nicely, it's not just an increase, it's an accelerated increase going upwards. And that's where we take the data and use the models for the prediction. And this is always under the assumption we will be successful to reduce greenhouse gases. We cannot continue with the increase, because currently this is attributed to the increase of greenhouse gases, the warming, and if we are continuing along that track, this will be very steep. That means we will be flooding the entire areas around coastal areas. And that's where megacities are growing today. We have to act today to make that area livable in the future.