Hello again.

Welcome back to Larscience. In this episode, I'm going to talk about one of my favourite subjects: clouds! Aside from the fact that they're really cool, clouds are incredibly important for climate and we actually know surprisingly little about them, despite how common they are.

What is a cloud?

It sounds like a stupid question, but it's one that we should iron out from the beginning: what actually *is* a cloud? Simply put, a cloud is a collection of water droplets or ice crystals that forms in the atmosphere.

You see them at altitudes where the temperature is cold enough that the water vapour – that's water in gaseous form – transforms to liquid or ice. That process, as I'm sure you know, is called condensation. That condensation occurs when the air becomes supersaturated with liquid water (or ice). The term 'supersaturation' means there is so much water vapour in the air that some of it is forced to condense into liquid or solid form, which in this case, means into a cloud.

The reason this happens is because air can hold different amounts of water at different temperatures. So if you have air with the same amount of water in it, at ground level you wouldn't see a cloud, but at, say, a kilometre above the surface, you would. And that's because the temperature is usually warmer near the surface than high up in the atmosphere.

Those temperature differences are part of the reason that different places can have very different amounts of cloud cover. Some places are almost constantly cloudy, like the Larsen C ice shelf that I study, while others very rarely see any cloud, such as hot, dry deserts, for instance. Other factors that influence clouds are things like whether there are any mountains, and the weather and conditions at the surface.

Why are clouds important?

Now we all know what we're talking about, I suppose the next question to ask is: why should I care? What makes clouds special, apart from the fact that they're nice to look at (as long as they're not raining on you)?

Clouds are very important for influencing the amount of energy that is received at the surface. The amount of energy that comes from the sun, which we call the solar radiation flux, is for all intents and purposes constant. The amount of energy that reaches the top of the planet's atmosphere doesn't really change much because the sun kicks out pretty much the same amount of energy all the time. What does change though, is how much we get at the surface. That's partly because things in the atmosphere, including all the gases that allow life to survive, like oxygen, nitrogen and water vapour, absorb and reflect this energy, i.e. they get in the way of the energy coming down, and also in the way of the energy going back up! Funnily enough, because clouds are made of water, they do this too.

Clouds affect the amount of energy that gets to the surface in several ways. I'm only going to talk about the two simplest ways they do this, so I'm intentionally neglecting their effect on the water cycle, and their other secondary effects. Clouds have lots of different, complicated effects, but I'm not going to go into those here.

Right, disclaimer done, off we go. The first way they interact with solar radiation is by acting as a mirror. They reflect some of the solar radiation back into space, and behave like a shade, preventing energy reaching the surface. That's because they're white, and white things reflect more energy – think about how much hotter you get wearing black clothes in the summer compared to if you wear white or another light colour.

The second way is that clouds behave in the same way when we're talking about energy that's traveling upwards back out into space. The surface of the planet emits and reflects energy too: we call this outgoing radiation. The thing is, clouds get in the way, and re-reflect some of this radiation back down to the surface, trapping it like a blanket.

What I hope you've taken from that is that these two effects act in opposite directions. That is, they compete. On the one hand, clouds have a cooling effect, reducing the amount of energy that gets to the surface, but on the other, they trap heat that would otherwise escape to space, with a consequent warming effect at the surface.

How do we represent clouds in models?

Now that is what makes clouds really tricky for climate models. For one thing, clouds are usually much smaller than we can represent in models because our computers just aren't powerful enough yet. If you remember last episode, I spoke about models representing the world in gridboxes. The number of gridboxes influences the level of detail you can see – i.e., the resolution. You can think of it this way: if you have a low-resolution image, it's going to be blurry and hard to see the detail, but it won't take up much space on the hard drive of your computer. The higher the resolution, the better quality the picture, but the file size gets bigger and bigger. It's the same with model data.

So, to get over this problem, modellers make some assumptions. They're not always that realistic, but they don't break the internet every time the model runs, which is definitely a bonus. However, the problem is, it turns out that they're not that realistic at all, and in fact, clouds are the main source of error in climate models.

How do we measure clouds?

Part of the problem is that we don't really have many observations of clouds in the real world – they're actually pretty hard to measure. Weirdly, pilots don't often want to fly through clouds, where visibility is poor and there is likely to be lots of turbulence and other difficult flying conditions. That problem is compounded when you add Antarctic winds and temperatures into the mix, which come with extra challenges.

Unfortunately for us, that means we don't have a fantastic idea of the processes that go on in clouds, especially in polar regions. Now, Larsen C is a pretty cloudy place, so clouds have a significant influence on the amount of energy that gets to the surface. Because that surface happens to be made of ice, the amount of energy that gets there is important. It can be the difference between the surface remaining as ice, or it melting. With that in mind, it's easy to see how important they are for our understanding of climate change.

How does it relate to what I'm doing?

That's one of the things I want to improve in my work. If we can make those assumptions in the model a bit more accurate, then we can hopefully use it to look at how clouds will affect Larsen C, and its future. Of course, that requires more data, and more nail-biting trips through the skies. Lots of my research focuses on the balance between energy coming in and going out over Larsen C. We call that the energy budget or energy balance.

Generally speaking it is in balance, but when temperatures are relatively warm and there is more energy going in than is going out of the surface, that's when the ice can melt.

Figuring out when and where that is happening is really crucial to our understanding of what is going on on Larsen C, and what's likely to happen in the future. And clearly, that means understanding clouds is also critical. Luckily for me, that means I get to think about one of my favourite things all day. Winner!

Keen to know more?

The IPCC is the most comprehensive source of information on climate change, and produces reports every 6-7 years on the current state of scientific understanding. This chapter, from the latest report in 2013, brings together current knowledge about clouds and their contribution to uncertainty in climate models.

Don't forget I publish posts on a whole host of topics on www.larsenc.com (aka www.climategreat.wordpress.com) so don't forget to check out the other stuff on the site.

Selected references

Boucher, O. et al. (2013) Clouds and Aerosols. *In:* Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T. F. et al. (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA.

Stevens, B. & Bony, S. (2013) What Are Climate Models Missing? *Science 340* (6136), 1053-1054.

Wallace, J. M. & Hobbs, P. V. (2006) Atmospheric Science: an introductory survey (2nd ed.). Academic Press, London, UK.