Larscience – Episode 6 – Using aircraft for atmospheric research

Heyyyyy. Welcome back to Larscience with me, Ella Gilbert. This episode, we're going to be talking planes, trains and automobiles –except we're not, because we're just talking about planes.

Since the last episode I've found out that I'm going to Antarctica this field season, which is one of the coolest things that has ever happened to me, so please excuse my excitement. While I'm down there, I'll be doing lots of flights as part of my research on clouds and how they affect the Larsen ice shelf, and the Antarctic Peninsula more broadly. I know, right, pretty exciting!!! I'm going to be making a little film about the stuff I get up to down there, which I will definitely be posting when I'm back, so make sure you check that out.

Most of what I'm going to be doing will be flying through clouds on the British Antarctic Survey's retrofitted Twin Otter aircraft, which can measure a huge number of different things. As a result, I've had to do a lot of plane-related training (you know, just usual things like escaping from helicopters underwater and in-flight cabin crew fire fighting – 100% totally transferrable skills. I'll definitely use those in my day job). In fact, I wrote this script on the way back from my latest aviation-related training course. All of that got me thinking – it might be interesting to talk about all the great stuff you can do with aircraft measurements, and maybe also the downsides. I've written a bit about this too, in a post about how we measure clouds – I'll put the link in the transcript [https://climategreat.wordpress.com/2017/08/21/how-do-we-measure-clouds/] and you can also see it below the podcast audio.

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Anyone who knows me will know that planes aren't my favourite thing from an environmental perspective – they're the single most polluting mode of transport an individual can take, and aviation is the fastest growing source of emissions worldwide. I try to travel over land or sea whenever I can, and I can proudly say I haven't taken a short-haul flight since 2008.

So: why on earth am I doing a podcast about why planes are great then? The answer is that they are really useful for science, and especially cloud science. The thing is, clouds are generally pretty high up, and there are very few places where you can measure them directly from the ground. Even when you can, those are usually quite special conditions (like fog, or clouds high up in mountains) that aren't necessarily representative of the clouds you'd ordinarily see. So, getting up to cloud level is a bit of a challenge.

Of course, we can measure clouds from the ground, using instruments like lidar, which fires lasers at clouds and measures the way that the signal comes back to determine cloud properties like its height, or whether it's made of liquid water, ice, or both; or we can measure them from space using satellites that can do lots of the same things but from the top down. The trouble is, when clouds form in complex ways, like when there are several layers of cloud, all with different properties, it gets hard for these instruments to 'see' their full profile. Plus, because we're relying on a proxy measurement rather than a direct measurement of what you want to sample (in the case of lidar or radar that's the reflected signal that you get back), we need some way to check that what you're measuring actually means what you think it does.

That's where aircraft come in. Research planes are typically retrofitted light aircraft, like the British Antarctic Survey's twin otter, a little prop plane, or ex-service short-haul planes in the case of the UK's research plane, FAAM (I know right, possibly the best name ever. It's almost a shame, almost, that it stands for something – the Facility for Airborne Atmospheric Measurement). The point is, they are bristling with instruments that can measure pretty much whatever you want them to. The instrument payload is tailored to every flight campaign to match the science that is planned. And, because you're flying through the sky, you're flying through clouds, and can directly measure them while you're in them – that means you're getting a really high resolution in situ (i.e. in-place) set of data.

You can do a lot with that data – first of all, you can use it directly. Clouds are really important because they exert strong controls on precipitation and radiation at the surface. Clouds transmit and reflect radiation coming from the sun and going back to space – and therefore affect Earth's overall radiative balance (very loosely, that means whether the planet is warming or cooling). We call these characteristics their radiative properties. I won't patronise you by saying that clouds also affect precipitation, because I'm sure you all know that, but different cloud types generate different types of precipitation and in different amounts. Understanding both of these features can help improve weather forecasts, as well as our ability to predict how this might change in the future.

I'll give you a brief flavour of what you can measure from a plane, beyond simple meteorological and location data like altitude, pressure and wind speed. You can determine the temperature of clouds, their liquid and ice contents, the size and number of droplets and ice crystals, all of which have a bearing on cloud radiative and precipitative properties, the shape of ice crystals, which can tell you about the temperature at which they formed and how likely they are to precipitate, or the aerosol contents, which can tell us how the cloud formed and give us an indication of its lifetime. By flying through different layers, you can see how all of these parameters vary over geographical space, and with altitude. That profile can be really useful, and can tell us about the processes that are going on in the cloud.

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Secondly, you can use that data to check that what you're getting from remote sensing instruments – that term just means instruments that measure from a distance, like ground-based radar or space-based satellites – is showing what you think it is. That process is called validation, where you compare your remotely sensed data with your in situ observations of the same clouds. Then, you can adjust the algorithms for satellite and ground-based remote sensing so they better match the observations. That means you can have greater confidence in your remote sensing data when you don't have the luxury of aircraft data to rely on.

The third thing you can use it for is another type of validation – the validation of computer models. Because models are just our best understanding of real-world processes, represented in as complex a way as our best and biggest computers can handle, they are necessarily simplified compared to reality. We need to make sure though, that this simplification is not missing the point, and that the models still do a fairly good job of recreating present conditions. In the case of clouds, they often miss the point. Clouds are the most poorly modelled feature of the atmosphere in current models, and the largest source of uncertainty and error in our projections of the future. Reducing that error requires more data to feed into the models, and to tweak the maths behind how they create clouds and their effects in the model. Ultimately, that will improve the predictability of the weather on short time scales, and of the climate on much longer time scales.

So you see, aircraft play a really key role in guiding weather and climate research. The only problem is, research flights are hella pricey, and that's why there's not that many of them. Obviously, they can also only sample things on the path that they track, whereas other methods, like satellites, can get much more extensive spatial coverage. So there’s a need for lots of different data sources, as long as you’re confident that they’re all on the same page, recording the same things.

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In the Antarctic, all of these problems are confounded. It’s a pretty harsh environment to be flying in at the best of times, let alone when you’re being told by some insane scientist to fly through clouds, rather than around them, as any sensible pilot would do. It’s remote, inaccessible, and far away from help, should you need it. It’s also expensive to get all the fuel, staff and equipment down there. That’s mainly the reason why there is so little cloud data from the Antarctic. In fact, the 2010 JASPER campaign of flights that the British Antarctic Survey (I’m just gonna call it BAS from now on) conducted over the Antarctic Peninsula was the first since the 1980s. That unfortunately means we know very little about clouds there. It’s even more unfortunate because the poles are more sensitive to change than anywhere else. The Arctic is warming far more rapidly than lower latitudes, and until very recently, the tip of the Antarctic Peninsula was warming faster than anywhere else on Earth, trucking along at a rate of half a degree of warming per decade – or nearly 3 degrees in just over 50 years.

Antarctica is a particularly special place because it is so remote and cut off from the rest of the world. The raging Southern Ocean which encircles the continent means there is very little influence from nearby land masses, and makes the Antarctic Continent a ‘pristine’ environment. In other words, an ideal natural laboratory. That makes it a great place to observe clouds away from other factors that can complicate things, like human-generated pollutants or emissions from forest fires. Besides, figuring out what clouds are doing in Antarctica is extremely important for estimates of global climate change because cloud radiative properties there affect how fast or slowly the enormous volume of ice stored in the Antarctic ice sheet will melt. There’s enough water in Antarctica’s ice to raise global sea levels by 58 metres. That would mean goodbye to most of the world’s largest cities, and a dramatically altered world map.

I’m not just being biased when I say that clouds are crucial to study. They really do play a critical role. Improving our estimates of cloud properties will go a long way towards reducing the uncertainty currently associated with climate projections. That’s only going to get more pertinent as the decades wear on and the effects of climate change become more and more apparent.

Flight data can help identify the largest errors, and start to remove them. Antarctic flight data will assist us dramatically in predicting change there. Happily, I’ve got the chance to be a part of that this year. It’s amazing to be on the cutting edge of research like this, which can ultimately shape what we know and guide policy and action on climate. Like I said, I’ll be able to talk a bit more about this when I’ve actually done it. Right now, all I can say is that planes are unrivalled bits of kit to measure clouds and the atmosphere from, and equipment that could be used even more to improve our ideas about what the world will look like in a few generations’ time.