Topic 4b - Part 2: Tracking the transport and effects of aerosols with satellite data and models

We can't see the atmosphere. So we assume it's mostly gas. But of course, it has got particulates in it as well, and in particular, aerosols. Tell us a little bit about what an aerosol is, and the different types that exist.

Yeah, there's many different types of aerosol. When you think of aerosol, you should think of a little particle, which can be any kind of shape. It can be suspended in water. But essentially, it's not a gas. And it's a very complex subject, because there's many different kinds of aerosols, many shapes and sizes.

So it can extend from things like dust. Dust is an aerosol. So large Saharan dust plumes, large aerosol plumes lifted off the desert. Volcanic ash is an aerosol. You get sea salt. You get sulfates. You get many different classes of aerosols. That includes things like sea salt, which is blown up of the sea from white caps in the ocean. You have desert dust. You have volcanic ash. But you also have particles that are emitted from large biomass burning-- from the exhaust pipe of your car, from industry, from other kind of industrial sources.

So there are many different kinds of aerosols that we see in the atmosphere. And that they're not all the same. The particles are different shapes, and sizes, and characteristics. And some of them might even be essentially a solution in a water droplet. So they're either spherical particles, which can be in water or asymmetric, more solid things. Even ash, volcanic ash, can be very different, depending on the rock that was underneath the volcano when it exploded.

And aerosols are interesting, because they are transported through the atmosphere in different ways. It's fine you put them up there, but then, there's actually quite a lot of difference between the way that different types-- where they'll go and how long they'll stay up.

Yeah. And a lot of that depends on the size and the mass of the particle. But it also depends how high it gets in the atmosphere. So anything that is emitted and gets stuck in the troposphere-- so that's the part where the weather is, where things are a bit turbulent, where you get rain-- they're much more likely to be rained out, to essentially be deposited back on the surface of the Earth.

When aerosols get ejected very high-- when you get, for example, a very large volcanic eruption, and get into the stratosphere, then they can have a longer lifetime, because they're up in a more stable part of the atmosphere. And they can have quite significant influences on the radiation balance when they're at those high levels.

So you work on things in the atmosphere. When you look up-- you climb a mountain, for example-- and you look out at the atmosphere, what do you see in your mind's eye? We see through the atmosphere, but how do you see the atmosphere?

I guess I am quite interested often in the color changes. If you're standing at the top of the mountain, you can often see you've got your blue sky above, that's really, really blue, and then you can see the haze level, often a slightly different color.

So that's what I'm often quite interested in, is, what am I looking out at? What is causing that haze? Is there a city down there and there's a lot of pollution in the atmosphere? Is it a desert? Is that what I'm seeing? Some desert dust creeping up into the atmosphere?

So I tend to look at things like that, and how much visibility-- because, obviously, if you're at the top of the mountain, you've got fantastically clear, often, visibility across the scenery you're looking at that's on the same level as you, but as you look down, you really get a sense of there being stuff in that atmosphere.

And we think of the atmosphere as being invisible, because most of the time, it is. But the things in it are not necessarily invisible. But they are very hard to see. Tell me about some of the things in the atmosphere that you study.

So I study things like sea salt and desert dust. Sea salt is a fantastic example. If you're near the sea, you often can feel sticky on your skin. But you don't look and see sea salt. But it's there in the atmosphere. It's sticking to you. It has effects on you, your car, windscreen, things like that. Same with desert dust.

Often, every so often, you might get into your car, and have to use your windscreen cleaner to clean off very fine particles. And you might notice it's very dirty. It's very dusty. And that could be desert dust that's coming up from Africa that's being deposited onto your car.

And these are particles that we call aerosol particles.

Yes.

And then this picture behind us-- now, this is a picture that a lot of people in the UK took. And it was a day when the sky went red.

Yes.

So tell me what's in this picture here.

So here, obviously, you've got a picture of the sun. And then you can see that, rather than a blue sky behind the clouds, it's this really kind of yellow color coming through. And so what we're really seeing here is the effect on these small particles-- these aerosol particles-- and how they're influencing the light that's coming through the atmosphere to us. So you could really notice it. I think a lot of people really were aware of this changing color of the sky. It was very dramatic.

So small quantities of these particles are present all the time. But sometimes the number goes up, and that's the sort of thing that you study?

Yes. Yes. So sometimes, you might not have any. You can see very clear visibility. But yes, the number goes up. And then you have something like this that occurs. I mean, this is very dramatic and noticeable.

So this is the sort of thing you can imagine being able to measure from a satellite when the whole sky has gone a funny color. You would be able to see that from high up. So how useful is satellite data in studying these tiny particles?

Well, it's very useful in that it gives us an overall idea of how much aerosol there might be in a column of the atmosphere. So we have here a picture. This is one of the observations that we use in our forecasting system. And this is aerosol optical depth from the MODIS satellite. So what it's measuring here is, really, how much the light is being obscured by these small particles in a column of the atmosphere.

So we've got a map here. So we can see Britain's up there. And Ireland's there. And then Europe, France, and Spain are down here. And Africa is down there. And then there's all these bright colors.

Tell me about the colors.

Yes. So the bright colors show us the aerosol optical depth. So the darkest are these high-color, red colors here. They're very high aerosol optical depth values. So it means that the light's being obscured quite a lot in those areas. Whereas, when you've got the lighter yellows and the whites, that means you've got a much clearer atmosphere. So this would be where you'd see-- you could see haze. Or in this case, quite good visibility.

So that's great. You can imagine looking down from the atmosphere, and seeing-- just as if you were looking down through fog, almost-- how cloudy the ground is. But then we can see weather on top of this.

Yes. Yes.

And all of these clouds. And how does this change those measurements? So we can't actually make measurements when there is cloud, because the satellite is measuring how much a light beam going down to the surface, and bouncing back up, is being obscured by these particles. But of course, as soon as you've got cloud there, the light beam's not getting down to the surface to bounce back up.

So we don't have any observations where there's cloud. We can only really have it where there's clear sky.

So the satellites are great, apart from when it's cloudy? Is that right?

Basically, yes. And what you can see here is, this is the event that caused that orange sky. And you can see it was caused partly by the Hurricane Ophelia coming across. So this is in October 2017. And you can see the hurricane here. And of course, that was pulling up aerosols from Portugal and from the Sahara. And you can see that the information that we really want, which is what the aerosols are across the UK, is being obscured by this big weather system that's coming up here from Hurricane Ophelia.

So there's something important here, then, which is that we can see that you've got some satellite data. And that must be useful in this situation. Whatever data you've got, that's useful--

Absolutely, yeah.

--but you haven't got everything. So how do you deal with that mismatch?

So what we do-- or what my role is here is at ECMWF is to look at how we combine the model and the observations to get something that's actually usable by the general public. So we, in effect, fill in the gaps in the observation. But even more than that, the observation is just how much the light is being obscured by small particles in general. It doesn't give us any information about what those small particles might be.

So with the model, we can identify what the small particles are, and whereabouts in the atmosphere they are, as well. The observations here-- observations of the full column-- and we really want information closer to the surface. We're interested in what's affecting us down here. So then we can use these observations and combine them with the model in a way that we can get useful information for us.

So it's not that you're just coloring in the gaps randomly. It's that you have a weather model that goes with this. It tells you how the wind is moving, and it tells you what else might be going on. You might have had data from the previous day that showed you stuff. And you can use those intelligently to fill in the picture.

Exactly that. Exactly that. So our models are not perfect. We do our best, but we work on a larger resolution than nature, which obviously can be very small scale. So the observations give us information that means we can adapt our models. So we need both. We need the observations to really anchor and give us information on where our model might be going slightly wrong.

And then, we need the model, because that gives us the real specific information we need for the forecasts-- for telling people what they actually want to know.

So it's a constant process of checking the data. Run the model this way. Check you've got the physics right. Check the data is going in properly. And then, you produce something that is actually useful to a person on the ground.

Absolutely. Exactly that. Yeah.