Topic 1f - What we measure – overview of key parameters measured with satellite

[MUSIC PLAYING] Satellites are first of all just platforms. It's like a bus, the bus in which instruments travel on. And these instruments are very complex and cleverly designed. And these provide observations.

Remote sensing is what this area is called. And we remotely sense or sound. And we measure in the atmosphere gases, aerosols, cloud, temperature. In terms of the pollution, the chemical weather, we need to measure the key chemical constituents and the vertical and horizontal distributions and the temporal variation to be able to understand what's happening.

Now we have local phenomena like a smog, a summer smog or a winter smog, which are kind of short lived. And we also have things which are game changers on the climate. And they're the long-lived gases like CO2 and methane. And they're the issues to measure very small changes against a growing background signal. And the issue with the pollution is to measure short term, very precisely.

The evidence on the changing nature of the impact of man on our planet required really for legislators in the first case to be able to design policy which mitigate the impact of man. There are services related to this, which are coming online using this data. But I think from my point of view, the fundamental thing is to provide the evidence, to test whether we understand what's going on and to be able to improve our predictions in this non-linear system to understand how this system will be in 10, 15, 20 hundred years.

Tell me just a little bit about the concept of a satellite. What can you see? What do you need to make a satellite work? What are all the bits of the system?

Well, the whole system for a satellite-- well, first of all you obviously need the instrument, the instrument that you build with a particular specification in mind. And you put it on the platform. Once it's in space and once it's in orbit and has been launched and it's making observations, you have to first of all verify that you have good quality data, that it's well calibrated then you have to verify that the products you're making are scientifically meaningful.

So you need ground-based systems that you can use for validation. You need systems to transmit the data from one place to another. And then you need an overall ground system where you can make the final products that go to the user. So this is the satellite part of the system.

So the product, that's the data or the visualization or the numbers that a user would see. But there's all this stuff behind it that goes into making it.

Yes, all the data processing. So what we get from a satellite is typically some kind of physics counts, I suppose you could think. And there's a lot of data processing that first of all turns that into physical quantities, which could be a measure of radiation. And that is the basic quantity that we use to infer something about the atmosphere. So in between each of these steps is some very complicated processing that's happening to generate an end product that's something you could understand as a parameter of the atmosphere, that you could understand as something scientific you want to know about.

Satellites are varying distances away. But it's a long way. And the idea that you can know anything about what's happening down here from up there is an amazing thought. It involves a lot of deduction. It's almost like a detective story, isn't it?

Yeah. There's a lot of unraveling what you're seeing. So there's different elements of what you see in your measured signal. So what you're ultimately wanting to do is separate, and in our case for the atmosphere, signals that come from the atmosphere from signals that, for instance, come from the surface or come from other contributing things that you're not interested in.

And often for atmospheric composition, we use measurements of radiation that are actually quite high spectral resolution. So you're looking for the way a gas component or particle interacts with that radiation, how it changes it, how it scatters the light, how it absorbs the light. And you have to remove that information out of the signal to come back to how much of the quantity was there in the first place.

We've got this picture of them being kind of all seeing eyes. But they're not that, are they? There are things they can measure and things they can't measure.

Yeah, if we think first of all, one is the spatial scale we can see on. If we're looking at trace gases in the atmosphere, so small, small quantities, we often have to collect a lot of radiation, a lot of energy to get that signal out. So the footprints are not necessarily that small, depending what you're trying to see. They might be of the order of kilometers. So you might find, in our case, if we're looking for very small trace gases, that we're not going to see something the size of your back garden. We'll see something maybe with the newer generation of satellites that might be getting towards city scales, getting towards center of city scales.

And the other way you have to look at it is if you want to get information about the really lowest part of the atmosphere where you might have pollution, where you might have air quality. You want to see the very lowest part of the atmosphere. This is what we walk in outside. And that is quite difficult to separate from what's going on higher up.

So you have to formulate your problem. You have to decide what it is you want to know. And then you have to tailor your measurements so you can get the pieces of information that are important out.

A satellite is not going to know what's happening indoors, for example, or underneath a tree canopy. So there are places that they can't get to.

They can't get to, no. And for us, a very big complication is cloud, actually. When you're looking for minor trace gases and you look down, you'll know that if you've ever been in a plane. You look out the window and all you can see is cloud.

Well, if you're looking for a very small amount of a gas from the position of a satellite and there's a cloud in the way, it's clearly a problem to see underneath the cloud. So that's one of the things that is a limiting factor often when we're trying to look at pollution, for example, or anything that's coming from the very bottom of the atmospheres is clouds or of course houses and trees. But we're not able to look inside your living room, not yet.

Probably a good idea.

Probably not, yeah.

And tell me a little bit about the types of satellites.

Yeah, one of the types of satellites that we have used a lot in classical meteorology and we're starting to use now in the area of atmospheric composition is a geostationary satellite. So that's rotating at a very high level at 36,000 kilometers. It's rotating at the same speed as the Earth. So it's sitting looking at the same place on the Earth at all times. And what that allows you to do is get a very high time resolution.

So you're sitting, looking. You can either have the satellites that spin and then they take a view every time they go round. You can have stabilized satellites that are scanning. But the main feature is that they allow high temporal resolution. And that's very interesting when you're looking at processes, when you're trying to look at emissions from the surface, when you're looking at anything that's very dynamic.

So as the Earth rotates, the satellite is going even further around the outside, but it's looking just at one place. And so it is always looking at the same place.

Exactly, exactly. Yeah, the other classical element of many operational systems is the polar orbiting satellite. So that's orbiting the Earth in a regular cycle such that it always crosses the equator at the same local time. And then you typically get something like 14 orbits a day going around.

But you're getting-- it's much closer to the Earth, maybe seven to 800 kilometers, so it's easier to collect the energy. But it's moving. It's moving relative to the ground seen. So you're taking images as you go around. But that gives you very good global coverage.

So you have the difference between the global coverage and looking at the geostationary view where you have high temporal resolution. And you can marry these together. They're, of course, mixed orbits, different kind of orbits, highly elliptical orbits, other orbits you can use for particular problems. But these are the very classical, typical ones you use in an operational system.

There's a lot of different earth observation satellites up now. But there are some, particularly at the moment, the MetOp and the Sentinels, or-- tell me a little bit about those different satellites.

Yeah. At the moment, current operational suite of satellites, it comprises two main parts. There's the Meteosat Second Generation. That's the geostationary system that's currently still largely devoted to meteorological applications. But there are some applications for composition that it can support, so things like detection of volcanic ash and these sort of problems.

And then we have the MetOp system. That's the first big European contribution to a polar orbiting system. And we have a whole suite of instruments on board.

And for the purpose of composition, we have the IASI instrument, which is a spectrometer measuring in the infrared. And we have the GOME-2 instrument, which is measuring in the UV invisible. And these two instruments together can give a lot of information about a wealth of trace gases. So this is what we have currently.

MetOp has three operational satellites in the whole long-time series. And we currently have two in orbit. The third is due to be launched very soon. And then we will be looking towards the next generation. So the next generation of both the geostationary and polar orbiting satellites will build on that heritage, but complement it with newer instruments, newer, more exciting instruments.

Right. So tell me about Sentinel-4, for example.

Sentinel-4 is a contribution from the Copernicus program, which is initiative of the European Commission. And it will sit on our Meteosat Third Generation sounding platform. So it will sit in the geostationary orbit. It's a UV visible spectrometer. And its focus is really Europe. It's looking at European air quality.

So it will be sitting in the geostationary view looking over Europe. It won't look over the whole disk that you can see. And it will be scanning every hour to measure a number of different trace gases that are pollutants with the focus on looking at air quality in Europe in a very regional scale. And it will have really some of the best resolution we've seen, in spatial terms that is. It's also the first time we've had such an instrument in geostationary orbit.

We're all taught at school that the atmosphere is 78% nitrogen and 21% oxygen and then there's some other stuff. What you're looking at isn't really those-- we take the oxygen and nitrogen for granted.

Yeah, we do.

What comes further down the list? Tell me a little about that.

Yeah, from the satellite point of view, the first thing that was really a big contribution from the satellite world was ozone. And that was ozone in the stratosphere. So that was ozone at 20 to 30 kilometers, around 25 kilometers where the ozone layer reside.

But now we're starting to be able to monitor ozone in the troposphere where it's actually a bit of a problem. And it's a health concern at the lowest levels, things like nitrogen dioxide, sulfur dioxide, so reactive gases that are emitted from transport, from energy, from other things, also things that are emitted biogenically. So we have reactive species that we're monitoring from the point of view of air quality.

And we're also starting to look at greenhouse gases. So there's a very big initiative, of course, to start monitoring our greenhouse gas emissions. And that's also something where you have a really big need for surface sensitivity. You need to see what's coming up out of the emissions from industry, from forests, from the whole cycle between biogenic and anthropogenic emissions. It's very interesting. But there's a big focus on anthropogenic emissions, of course.

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