EUMETSAT

Topic 4c - Part 1: Monitoring volcanic emissions - Overview

So let's start with this animation behind us, tell me what we're looking at.

So we're looking at images taken from a geostationary satellite called Meteosat Second Generation. And, that satellite flies 36,000 kilometers above the earth over Africa. And at the rate around the Earth which is the same as the rotational speed of the Earth, so it always sees the same thing. And it observes the earth in different thermal bands, and also visible bands.

And these you can combine with RGB techniques to provide colorful animations like this here. And here we see clouds, ice clouds, water clouds, in different shades of brown and green. But most importantly, for our purposes today, we see an eruption over Eyjafjallajokull, which happened a couple of years ago, and we can also see the ash cloud that is coming out from that volcano eruption.

So Iceland's up there, and this was the big volcanic eruption that stopped air transport across the northern hemisphere for a few days, wasn't it? And it was a big event. And this is what was happening in the atmosphere. So tell me what is the pink stuff here, what are we looking at?

So the pink stuff here is really volcanic ash, and this is what we can see quite well with these geostationary satellites. You can also see a little bit of SO_2, but ash is really the prominent feature, and the one that has the greatest impact on aviation.

And what sort of problems does this stuff cause for aviation, for airplanes?

Well the ash actually interferes with the engines, and it actually can cause a glass formation inside the engine, which actually could stop the engine from working. But what's important for us was that through Eyjafjallajokull eruption, we got a much better understanding on what the limits are for aircraft and their engines to operate in conditions with volcanic ash, and for us as data providers, to understand what kind of information they really need.

There was a big debate at the time, wasn't there. Shutting down air travel across the North Atlantic was enormously costly, inconvenienced a lot of people. No one wanted to be in a plane that had ash in the engine, but on the other hand, it was expensive and difficult, and there was a bit of push back against whether the planes should be allowed to fly or not. And this is the kind of information that can sort out that debate, right?

Absolutely, and this is what we can do with our instruments today. But we will soon, in a few years, launch the Meteosat Third Generation satellite with new instrumentation, infrared sounders better imager, and other instruments. And with those, we can characterize the volcanic ash clouds much better, the type of cloud which is there, its height and also its

imperative space

constituents.

And the thing about ash, the first important thing, is how big the particles are. How good were the satellites then at telling particle size, and how good will they be in the future?

Well, this is a bit difficult to quantify, but of course today they are not that good. And this animation basically only shows where the volcanic ash cloud is, it doesn't necessarily give the thickness of the cloud, or also it doesn't give the particle distribution size. But this is what we can get a better handle of with the next generation satellites.

And the things that come out of a volcano, it's not just the ash, it's also the sulfur compounds, tell me a little bit about those.

Well the sulfur compound and the ash is problematic from the point of view that they actually may end up in different layers of the atmosphere and go different ways. So you really would need to monitor both of them. SO2, the sulfur is mainly just an unpleasant effect through the smell, but it may also have some corroding effects which also the aviation industry is looking at. But that doesn't seem to be that dramatic today.

And these emissions from volcanoes also have effects on the climate, don't they, weather and climate, how does all of that work?

So that's very interesting, because in 1991 as you know, Pinatubo erupted, and this was the second most dramatic volcanic eruption in the past century because of the cooling of the atmosphere by one degree Fahrenheit, which is half a degree centigrade, roughly. And that cooling lasted over a couple of years.

We think about the eruption from a volcano, it's obvious that there's a huge amount of material. But the stuff that gets up really high is very small and very fine, and yet it can have such a huge influence on the atmosphere. That's acting like a parasol isn't it, an umbrella? Shading.

It does block the solar radiation from coming into the atmosphere, and it actually slowly spreads itself over most of the globe, also towards the poles. And that's how the atmosphere works, it just spreads everything around. And it blocked radiation from coming in, and therefore we had less heat by the surface.

And it's important to say that there's long term climate change and these natural events are causing spikes and bumps, especially volcanoes along the way. But still, the climate warming trend is still continuing, but all these little spikes are kind of additional to that trend.

And that's why it's really, really important that we work on climate data records, not only on a global scale, but we look at regional impact. So that we actually can separate between anthropogenic causes for climate change versus natural variation.

The volcanic ash, of course, comes from volcanoes. This is an animation here, what we do with our model of a very recent volcano. And what we show here is how the volcanic ash emitted at this point in Indonesia from the Sinabung volcano is transported vertically throughout the atmosphere.

So this is what we're used to thinking of when we see a volcano. There's a big plume of gas and particles that go up, and they can go a long way up these particles, can't they?

Yeah they can go a long way up, so basically, two things are emitted by volcanic eruptions. This is one, the fine ash, and then the other one is sulfur dioxide, and both contribute to the aerosol load of the atmosphere.

And so what we can see here is those particles just being carried by the wind and spread out. But the thing we think about ash, if we sit around a campfire or something and there's some ash, we know that even just a little distance away there is ash falling down. So this isn't just about where the wind goes, it's also about how quickly things fall out of the wind. And how does that work for different types of-- because you have different types of volcanic ash, right, they behave in different ways.

I mean in a volcanic eruption a lot of material is sort of put into the air, and most of it is deposited directly around the volcano, and this is actually the problem for the people living here. What we consider here is really the material which gets airborne, and for this reason has to be very, very tiny, so really you're talking about aerosols here. And the other thing that is emitted is sulfur dioxide, which is a gas, basically, so it's not particles. And they are erupted up to 10 to 20 kilometers into the atmosphere, and can even reach the stratosphere.

And then, depending whether they reach the stratosphere or whether they are still in the troposphere, they have different removal pathways. Once they enter the stratosphere, they will linger there for a much longer time, we're talking here about several years for certain really major eruptions. Fine ash, which is maybe coming more to the troposphere, is transported sort of in a timescale of a couple of days, and then it's settled down and it will be removed from the atmosphere again.

And there's an industry which has a particular interest in how long volcanic ash stays in the atmosphere, and that is the airline industry, because obviously they stop quite often if there's a lot of volcanic ash generated. They stop flying because it's not safe. But the big question is when can they start flying again and where are the edges of the safe area. And, how do models like this help with that problem?

And the models give you a very good indication where the ash cloud is moving. So we know from the meteorological modeling of the wind fields, and this is basically the starting point for these kind of models, you have to know the wind fields. But the wind fields are not always blowing the same direction, we have what we call wind shear. So in different parts of the atmosphere the wind goes in different directions. So it's really dependent on the injection height in which the ash cloud is moving, and there are examples of where the ash cloud really goes in two different ways because they were emitted at different atmospheric levels.

So it's not a case that if a volcano goes everyone should stop for the same length of time. You need modeling like this to say this time you only have to stop for two days, you don't have to stop at all. It's a huge amount of money involved in the airline industry, so it's very practical tool, this.

Yeah, it's very important. I mean there's a lot of uncertainty included in this. So for instance, we have only a very rough idea if you see an ash cloud like in this picture how much material it actually is, so we are talking about orders of magnitude of uncertainty here. And what we try to do is give the people interested in a certain indication where the ash could move to, to give them a warning. But one should probably also look into sort of a scenario approach where everyone says OK, this is the most likely one, but there's another one which is maybe also a possibility. So it's really important to cover the whole area where there is a potential that ash can go to be on the safe side.

And you had another example of a volcano, I think, right? Yes, so tell me what this data is all about.

So far I've mainly talked about modeling, but we also want to, of course, observe them from space, and because they are very rare events, we don't see them very often. But this is an example of the Sinabung eruption, where a specific satellite instrument, which carries a lidar, which basically is an active instrument where you can make very precise measurements also of the vertical profiles. And this is a plot showing these measurements from this CALIPSO Lidar. And what we see here is the vertical extent, so this is in height here, this is a flight track of the satellite as shown in this graph over Indonesia, and in the redder bits this gives us an indication that we have a very high ash load in this area.

So what's going on here is that the volcano is here, and it just so happens that the satellite has passed over the top as this was all going on. And it's flown along its track, and it's measured downwards, and so it can actually tell you what depth the ashes are. And that's useful, because you can see it's very specifically here and not there.

Yeah, what we always find surprising is how actually thin these layers are. In our model, the vertical resolution is sometimes much coarser than these layers, which we see in the observations. But it's really interesting that in nature the layers can be very thin, and they remain thin over a very long period because there is not so much vertical mixing in these areas of the troposphere.

So they turn to slide along in layers, and things stay in the same layer.

In this block, you can also see the mixed layer, what we call the boundary layer. At the bottom here you see we have also higher values of aerosol backscatter, but the values are much more mixed here. And then at its height for the volcanic eruption, we have this very distinct layer, and we have layers where we have very little aerosol below and above.

So the satellites are giving you-- it's not just the top down picture. But it's not all satellites that can do this, it's the active ones that send the signal and come back, that can give you the vertical information?

The active ones are very good at giving us very detailed vertical information. We have other satellites which give us some idea of where the plume is, but they don't give us this nice vertical resolution. And so all of this, again, is assimilated into models that can just allow us to plan. Fundamentally, this is about planning for safety, right? We can't change when the volcano is going off, but we can change whether or not we get in an aircraft, or where we fly.

Yeah and this is really what is so important about CAMS, this expertise in using satellite data. What we saw before was just model plumes, so basically you can always question them. But if you have observations and you can mix them together, then you really get a much better forecast than if you would only use a model.