

Topic 4c - Part 2: Monitoring volcanic emissions - Case studies & the role of VAACs

When we're thinking about the uses of satellite data, we might think about climate change, for example, air pollution, but there's also things like security and environment security.

Yeah.

Tell me a little bit about that.

Yeah. This is a very interesting topic nowadays, and coming more important every day. And, in Europe, I suppose, that it started with Eyjafjallajökull eruption in 2010 already.

Which was the big Icelandic volcano.

Yeah. Big Icelandic. We closed the airspace completely. And, at that time, it was realized that the real-time monitoring is really needed. Upper left, we have the Kasatochi volcanic eruption, which happened in 2008, and SO₂ coming from this pool. And we can see the long transportation. It spreads from Aleutian Islands to Europe.

So this is sulfur dioxide, so there's gas that's coming out of the volcano.

Yes. Yeah. It really is quite a lot of SO₂ into upper atmosphere in stratosphere. And this is a good example of long-range transportation which happens in atmosphere. So because this SO₂ cloud, it reached Europe.

So even though the volcano itself was on the border between Canada and Russia, it was a long way away--

Yeah, yeah.

--there's one atmosphere. And all these things get shared.

That's true. That's true. This is the recent Vanuatu eruption in 2008, and this is also SO₂--sulfur dioxide. And we can see how the SO₂ cloud spreads from Vanuatu, and there's several eruptions going on.

First, we see something. Then, there are some days, we cannot see anything. And it repeats itself. So this is one example of a long-term degassing of volcanoes, which happens all the time. Although, in this case, we had some real eruptions also releasing some aerosols--volcanic dust or ash.

So there's a difference between the volcano just quietly--

Yes.

--just gases coming out, but it doesn't look like anything's happening, and then you get the big eruptions.

Yes. Yes.

And this has been really important recently hasn't it? Because the Vanuatu government has been moving people away from some islands--

Yes, yes, yes.

--because of these eruptions, and they'll be using data like this.

I hope that they are using this kind of data. If you have something like Vanuatu, we know the situation very well because the people are living there and it's small-- island only. And there's no other countries nearby. This could be affected, in fact. But the situation is very different if we have a Iceland volcano eruption because, what is the worst one, is this volcanic ash if it spreads to Europe. It may affect flights, for example, or economical conditions.

So as a whole, even though it's just one volcano a long way away, you can follow it downstream, and it affects more and more as it goes.

Yeah. Yeah.

And how about these two on the bottom here?

Here we have an ESA animation first-- this one-- which is ESA IASI index. This is Calbuco eruption in 2015. And we see volcanic aerosols, which is volcanic ash, spreading from Chile to Atlantic Ocean.

Were these higher up in the atmosphere? Or were they low down where a citizen might notice them?

These are quite high, in fact. Although, in this case, we had also low-level aerosols coming, which affected Southern Brazil, for example. They're basically in ground level at that time. But these are quite high level. And this is also the reason why they are traveling so long distances. Because if the ash is near the ground level, it usually deposits quite soon.

So there's a difference. The place where the ash goes starts off in the atmosphere makes a difference to where it travels to.

Yes. Yes, the plume height is very important. And it's also very important to know for

modeling. Because the one input choice for modelers for using this kind of data is that, what is the plume height? What is the injection height for volcanic ash?

And how good are these satellites at that? Because the satellites are up, and they're looking down through the atmosphere. GOME and IASI, how good are they at knowing where it was in the atmosphere?

Not very good. Of course, LiDAR and these kind of ground-based instruments, they are much better. I hope that, in the future, this situation will be improved. But already, we are getting quite interesting results with GOME-2 to and IASI. We will release plume height products for both of those instruments later on within this AC SAF period.

So the satellites are the same, but your analysis is getting better.

Yeah. Analysis is getting better, and all the algorithms which we are using, we are continuously developing them taking new scientific input from other sources too. We are not just using expertise in our theme, but we are also using other scientific information and knowledge.

And how about this last one down there?

The last one is one example of SO₂ release within one year. This was 2011, and we can see IASI measurements-- IASI SO₂ measurements. And we have Nabro in Africa. It released quite huge amounts of SO₂ over a long period. And then we have Grímsvotn eruption in Iceland and that SO₂ cloud. And the last one is this Chile erupting volcano.

And the interesting thing here is you can see it doesn't go in a straight line.

Yeah.

The path that gas travels is-- you wouldn't necessarily expect that.

Yeah, because the gas is, as well as aerosol, they follow the air currents.

What we've got here is a picture of-- a representation of an event that happened in 1982, and this was where your field got started. Tell me about what happened.

Yeah, exactly. In fact, the story began in 1982 when a British airway aircraft flew into a cloud of volcanic ash over Indonesia and lost its four engines.

Which is a huge event. You're flying in a plane, a long way up in the sky, four engines gone.

Yeah, really. The volcanic ash was strewn up in the atmosphere by the Mount Gunung Agung.

It's an Indonesian volcano located in the southeast of Jakarta. And so after losing its four engines, the plane was diverted to Jakarta airport in the hopes that enough engines could be restarted.

And, finally, the planes succeeded in gliding out the volcanic ash cloud. And all engines were restarted and allows the plane to safely land in other Jakarta airport.

So it had a happy ending, but there was a very frightening moment when they could have lost a plane--

Yeah.

--just because of volcanic ash.

Yeah. This incident made the aeronautical community realize the danger of volcanic ash variation.

And what's volcanic ash like? Why does it cause problems for aircraft?

Well, in fact, volcanic ash is composed of silicates and is also made of very abrasive particles, which can damage aircraft engines when they are injected into engines.

The ash part right here, it's basically glass-- very sharp, hard glass. And it's flying through a jet engine, which has a lot of moving parts. It's very dangerous situation.

Yeah. Yeah, that's right. And because the ash particles have a temperature-- a melting temperature-- which is about 1,100 degrees Celsius, which is very close of the aircraft engine temperatures. So ash particles can quickly melt in the engine, and so, accumulate as a recently defined composite in the cooler parts of the engines, and so, damage the engine.

And so it was understood that we needed to study these volcanic ash particles. And the important thing is, what sort of ash is it and where does it go? So 35 years on, what's the system now for monitoring this? And what do we understand?

Yeah. With the occurrence of numerous ash encounters by aircraft, ICAO-- International Civil Aviation Organization-- decided to set up a global watch for volcanic ash. And so, therefore, nine Volcanic Ash Advisory Centers-- called also VAACs-- were created in the 1990s in order to watch over volcanic activity over the world.

So these are the nine here? So they divided up the world, and you've got one of those centers here in Toulouse. So what region are you responsible for?

Well, Météo-France is a French national weather service in Toulouse. It's in charge of the

Toulouse VAAC. And the Toulouse VAAC is in charge of the very large region extending from Western Europe to Asia and, also, including Africa.

And where are the volcanoes in that area?

Well, the most active volcanoes in the area are located in Italy, for instance, the Mount Etna volcano, but also the volcanoes located in the Naples region.

And once you have an eruption, where can the ash go? How far does it travel?

The volcanic ash can travel very far from the volcanoes-- about more than 1,000 kilometers. And so it can stay in the atmosphere for days, for instance, or longer.

And is the ash of all volcanoes the same? Or do different volcanoes put different things into the atmosphere?

Yeah. Volcanic ash can vary from one volcano to another, but this composition of ash is not taken into account by the numerical models.

Tell me a little bit about what the Volcanic Ash Advisory Centre and the London branch of it is for.

OK. VAAC London is responsible for forecasting where the ash from volcanoes in the Northeast Atlantic that are erupting, and for forecasting where the ash goes. So, that includes Iceland and a little tiny island called Jan Mayen, which is about, I think, about 1,000 kilometers to the north of Iceland as well.

So you've got some LiDAR. Tell me about the role of LiDAR in monitoring volcanic ash.

Back in 2010, one of the biggest challenges we had was-- actually, obviously, the forecasting was a big challenge, but also the observing, the monitoring, of where the ash was as it moved across the UK. I mean, it's not conventional, weather-type stuff, it's an aerosol in the atmosphere.

So we were able to use laser cloud base recorders, which are conventional ways of measuring how high the clouds are. Retuning those, to give us an idea, but only at very, very low levels. So it was conceived that it'd be a good idea to do something a bit more elaborate. And the UK government brought us some very nice new LiDAR.

They're research-grade instrumentation, so a little bit temperamental. It's taking us a little bit of time to actually get our heads around how to use them. But what they can do is observe layers of ash and other aerosols up to a cruise levels of the aircraft, right up to 35,000, 40,000 feet across the UK.

So we can now see where the ash is, in great detail, from the ground upwards, which is great because, obviously, what the satellites can do is to see what's going on with the ash from space downwards. So it really does complement the existing capabilities that we've got.

So where are the LiDAR? How many of them are there?

We've got nine LiDAR dotted around the United Kingdom. They are geographically spaced to give us good source-- strategic idea. So furthest north is up in Lerwick-- up in the Shetland Islands. Further south is down in Camborne, down in the far Southwest. And the others are dotted around at various places in between. We've even got one on the back of a wagon, and so we can actually redeploy that one as needs arise.

And have you had much practice with them? Because, obviously, the Icelandic volcano in 2010-- that was the big event. But we haven't had so many eruptions since then, so has it ever been tested as a system?

The way we test it as a system is to use dust from the Sahara a proxy for that, and there's been several events like that. We also tested it during the Portuguese fires. We were able to see lines of aerosol coming up across the United Kingdom during that.

And what we're actually looking to do with that is when we need to switch them on, because they're a bit sensitive. We can't have them on 24 hours a day. And, actually, using it as a way of how we teach our forecasters to actually look at difference between dust and ash and aerosol particles, which look completely different from water particles that we would see in cloud.

Tell me a bit about how that measurement fits in with the rest of the system, because it's not just one Volcanic Ash Advisory Center in one place. There's a huge network and a big international effort. So those LiDAR measurements, how do they feed into the rest of that system? What happens next?

Well, we go on to a website, and the moment we don't share the data as it were, so it's not raw data that we share, but the website and the thumbnails, as it were, at those ash in real time. What we detect using these LiDAR is available to anybody in the world logging on to the website.

And we've worked very closely with partners around Europe to make up a patchwork of, well, cloud-based recorders which have been retuned to look for ash and, also, research-based LiDAR in many parts of Europe and other parts of the world as well. It's been really, really interesting, because it's been about starting from scratch and coming up with a new observing network for observing aerosol up there in the atmosphere.

And how does that fit in with modeling and the services that are available as a result of all that?

That is the next big challenge, if I was honest. So for satellite imagery. We can't assimilate satellite imagery of where ash is now to give us a better source term for volcanoes. Certainly, we can do that at the Met Office to give us a better definition of what the volcano is doing at source, because that's fundamental to forecasting.

We're using those techniques now to actually try and integrate some of the LiDAR information we've got available to us as well. The technique is called inverse modeling. So it's like, this is where the ash is. And we've run it backwards to actually give us an idea of where it must have come from to end up where it was, as it were. And, at the moment, those techniques are based on those dust and sand proxies that I talked about, because we haven't had much ash to play with over the last six or seven years.

It's probably more comfortable for everyone that way.

And how about the international corporations? You've got lots of organizations. There's obviously lots of interest from the aviation industry, especially. But you've got national governments and national meteorological organizations and this huge web of people. How easy is it to get all of those work together?

It's a big challenge. One of the things about being a weatherman, a National Met Service, is that you can't do the weather without collaborating with everybody around the world. So what's going on in the Pacific Ocean will have an impact, eventually, on what goes on over Europe and the UK, and even down at the local scale in London.

We've had to mimic that approach-- that integrated approach-- with lots and lots of stakeholders in the Met community, but with academia and the private sector. And that's come up with new challenges because our skies and atmospheric composition and the Met Service world, we're very used to collaborating, sharing data, getting it around in near real time, understanding what it actually means.

Bringing new partners on board from academia and the private sector has been a challenge. I'm working out how all that works to actually deliver on what is an operational capability. It's not research that you can spend years and years developing, and look at the results, and what have you. When these things happen. Our customers expect results very, very quickly. Customers-- governments, the airlines, and, indeed, the public.

And what's the role of the World Meteorological Organization in all of this? So WMO is the UN body for weather, climate, and water. And what they maintain are the networks, or if you like the forum for us all to come together-- 191 nations around the world to come together and talk about the weather, atmospheric composition, hydrology.

They look after the sights. They look after the observations and a lot of the expertise and collaboration that we depend on to do our everyday work in the weather and the water sectors, and increasingly with the atmospheric composition as well. So they're a fundamental part of the deal, as it were.

And they also have this working relationship with the International Civil Aviation Organization, where if ICAO say, we need this to happen. Yeah, the clever guys with the science and the technical expertise. You come up with solutions to actually respond to our requirements. So they're a big and significant plan.