The Impact of Aerosols on the Environment

The Ocean Insight Grant Program encourages the use of spectroscopy for research promoting a safer, cleaner, healthier world. In this interview, we chat with former Grant Program award winner Santiago Arellano about his work analyzing aerosols.

Application Note

KEYWORDS

- Aerosols
- Atmospheric climate
- Volcanic emissions

TECHNIQUES

- Absorbance

APPLICATIONS

- Particle analysis
- Air quality monitoring

Intro

As a volcanologist, Santiago Arellano has travelled the world, studying volcanic emissions and their effects on atmospheric climate. In this profile, Arellano, a researcher in the Department of Space, Earth and Environment at Chalmers University of Technology (Gothenburg, Sweden), describes his grant-winning work measuring the properties of aerosols, which are fine particles and droplets suspended in air. This interview has been edited for length and clarity.

Q: How would you describe the work represented in your grant-winning proposal?

Arellano: We're building a system based on a spectral modulation technique to measure properties of aerosol and cloud particles in the atmosphere. This technique employs a broadband QE *Pro* spectrometer and a series of polarimetric optical components to measure the degree of polarization of light scattered by the particles. This informs us about the size, shape and composition of the particles, which is of great value in understanding the origin, transport, growth and impact of aerosols in the environment. Examples of these particles are those forming clouds from volcanic ash, forest fires, meteorological clouds or pollen particles.

Q: Why is it important to get a better understanding of these aerosols?

Arellano: Particles are interesting for a number of reasons. For example, they can affect human health by direct inhalation. But they can also alter the balance of energy of the atmosphere and the climate. And they still represent the largest source of uncertainty in our better climate models. Or they can disrupt our economy, for example, by altering air traffic when events like volcanic eruptions or dust storms occur. So, with innovative methods to measure and analyze the properties of light that interact with aerosols, we can gain some knowledge about what they are made of, how big they are, and what shape they have.

Q: How can you use that knowledge?

Arellano: Well, there have been a lot of problems recently with forest fires here in Sweden and in many other countries. And so, the polarization signal changes when you have round particles like droplets in the clouds -- or irregularly shaped particles like the ashes from combustion or from volcanic eruptions.

With the naked eye, you cannot see the difference unless it's a very thick plume. But with an instrument, you can see the signal in the polarization. And with a plume coming from a forest fire, it would be exactly the same thing. You will be able to distinguish between normal clouds and a cloud that is coming from a forest fire. And in this way, you could maybe detect, first of all, if there is a fire; and second, you could tell something about the number of particles in the cloud. For example, if it exceeds certain thresholds for urban air quality.

Q: That kind of insight can be very important.

Arellano: I come from Ecuador, and sometimes there you see the sky turning yellowish, and you're not sure why. But now we know there are huge forest fires in the Amazon Basin in Brazil, which produce particles that are transported by the winds, thousands of kilometers from the source. And the aerosols coming from the combustion of the forest fires produce these yellowish colors in the sky. There are no programs to monitor these fires. The only way that you see them is in the satellite pictures and then you can relate. But you're not sure; it's very difficult to measure. So if you have an instrument on the ground that's looking up and detecting the presence of these aerosols, at least you can inform the public about air quality issues. The quality of the air is not as good today, and it may not be because all of the control measures that they're taking in the country related to combustion from factories. It's because they cannot do anything about the forest fires that are happening in Brazil. If you can attribute the source of the combustion by measuring its particles, the policy implications could be completely different.

Q: Can the same kind of particle analysis be applied to volcanic emissions?

Arellano: Today we can measure the amount of gas that is coming out of a volcano. And we already have algorithms that detect the position of volcanic plumes, their altitude in the atmosphere, and in which direction the plumes are going. But if we could also detect ash in the plume, we can send a message to the centers that control air traffic. There are nine centers around the world, the Volcanic Ash Advisory Center (ssd.noaa.gov/VAAC/vaac.html), and they provide information about volcanic plumes affecting air traffic.

Q: How do aerosols interact with the atmosphere? How do they affect climate patterns?

Arellano: It's complicated because there are several processes acting at the same time. But I can tell you one good and one bad thing about it. For example, if you have many small particles injected in the atmosphere, they will act as seeds to form droplets. So you will have more of these smaller droplets and they will stay longer in the atmosphere. The cloudiness in the sky will change and you'll have clouds that last longer than they normally last. Also, you change the amount of radiation that is coming to the surface. You are reflecting back more radiation into space. So this could act as a cooling effect for the climate.

Is this good or bad? It could go both ways. You could say, yes, it's helping the climate to cool down the Earth. It's going against global warming because it's a cooling effect, which probably is good. But it could be bad as well, because if you have more clouds that stay longer in the atmosphere, you will have less precipitation. Instead of having normal clouds that just form and then rain down, you have these clouds that stay longer in the air and disrupt normal rain cycles.

Q: Accurate climate modeling is quite a challenge.

Arellano: When you talk about climate science, the scale of the problem is so big that the only way to make progress is to have good balance between your observations and your model. And in many areas, observations are lagging behind because you don't have enough observations or your observations are not accurate enough. One of these observations is related to particles in aerosols. You have enough instruments around the world to detect them, to observe them. But these instruments may not be accurate enough to measure certain particles or certain properties of the particles that will be important for the models.

You would like to know exactly what is happening with these particles. So, if you have an observation, if you have the data, you can say, OK, it only makes sense that I run my model for these specific conditions because this is reality. So you can make much better predictions and make progress. In science, it's always a balance between observation and modeling efforts.

Q: You are from Ecuador, which is a mountainous country, and have studied volcanoes for many years. How did you first get interested in volcanoes?

Arellano: Ecuador is very diverse, with the coast, jungles and mountains. I was from the highlands, and could see at least three, and sometimes four, volcanoes on the horizon from my home. But I never thought they were going to erupt, because when I was growing up, they were just covered by snow and ice.

When I went to university, there was a job posted at the local volcano observatory, and that was a perfect match because I worked on a volcano that I used to look at when I was a child. And I kept working there and when I finished my thesis, there was a big eruption. I was involved in that and I worked there several more years.

Q: And how did you end up at Chalmers in Sweden?

Arellano: I became involved in a project with [Chalmers volcanologist] Bo Galle, which was about many other volcanoes around the world. And I was invited to do my Ph.D. on this topic. So I came to Sweden but I could keep my connection with my home country, because my thesis was very much focused on volcanoes in Ecuador. But I could also extend this work to other places in the world. I've been doing this ever since.

Q: Ocean Insight has worked with your colleague Professor Galle and the Network for Observation of Volcanic and Atmospheric Change (NOVAC), which he coordinates, for many years. What can you tell us about NOVAC?

Arellano: NOVAC (novac-community.org) is a network of optical instruments that measure the gas emission from volcanoes. There's a group of around 20 volcano observatories in the world, and most of them are located in developing countries in Latin America, Africa, Southeast Asia and Oceania. At the heart of each instrument is a spectrometer that analyzes the light that is being absorbed by volcanic plumes. And so you have an optical system connected to a spectrometer that is looking through the sky. And when there is a volcanic plume containing sulfur dioxide (SO_2) gas coming from volcanoes, this gas absorbs the light. You can see that in the signal of the spectrometer.

The first instruments were installed back in 2003. And so far, there are more than 120 of these instruments measuring 40-50 volcanoes. The instruments operate automatically. That data is logged in the instrument, but it's also transmitted in real time to the volcano observatories, so they can track how much gas is coming out of the volcano.

Q: Why is that important?

Arellano: One reason is that it tells you if the volcano is active or not, by telling you how much gas there is. It could be that volcanoes are not erupting. They are only in a period of unrest. But if there is a signal of sulfur dioxide, you know that the magma is not far from the surface, so it may well end up being an eruption. You will, of course, combine these data with other kinds of information from seismology or deformation or whatever. It's also important to know the impact of the volcanic plume, for example, on air quality for air traffic, as I said earlier. That's because the instruments can also locate where the plume is. It's going, like, two kilometers above the surface to the northeast. And then you can report, OK, the air to that region may be affected by these emissions. And something I've been working on the last couple of years is also using data from this network to validate satellite sensors.

Q: Finally, although this isn't directly related to aerosols analysis, I learned of work you did with Bo Galle and others on a drone-based system for measuring sulfur dioxide in volcanic gas plumes. What can you tell us about that?

Arellano: Our main goal was to come up with a better idea of how much carbon dioxide is coming from volcanoes around the world. All volcanoes emit about a thousand times less carbon dioxide than what human activities produce every year. So, volcanoes contribute very little to the carbon dioxide emission in the atmosphere.

But something that came up in the last few years is that you can use drones to measure plumes from inside the plume. We went to a very remote volcano in Papua New Guinea, which the satellites had observed. Some volcanoes have huge emissions, but they are so remote there were no measurements in situ. And so you can detect SO2 from the satellite, but you don't know about other compounds in the plume that are also important.

So we went there and we tested several platforms like small airplanes and small helicopters and so on. And we had payloads to, for example, sample the plume and then bring it back to ground and then analyze it with an instrument, or to measure in situ inside the plume and then send the signal back with the radio and know the composition of the plume and so on. And one of the instruments was an Ocean Insight spectrometer, a Flame, flying below the plume and just measuring the flux. The same way that we do with a scanner from the ground or from a car or something. But just flying with the drone makes it a much finer measurement. It was a very successful campaign.

Ocean Insight

www.oceaninsight.com

info@oceaninsight.com • **US** +1 727-733-2447

EUROPE +31 26-3190500 • **ASIA** +86 21-6295-6600

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