Topic 1d - Unravelling the complex structure of the Atmosphere - Overview

You spent a lot of your time thinking about the atmosphere. When you look up into the sky, most people see blue and birds and clouds. What do you see in the bits where other people don't see anything?

I think the amazing thing about the atmosphere is when I look at it, I see something that is actually quite thin. It's a thin, blue envelope that makes life on Earth possible. I think we all know that there are gases in there like oxygen and nitrogen that drive life on Earth. But also, there's everything from very small particles to ice particles to a range of other trace gases, which are all incredibly important to the healthy functioning of the Earth's system.

And just tell me what a trace gas is. How small a quantity can a trace gas be? And what sorts of things come as trace gases?

Trace gases are very small quantities-- anything from about 1%, which is the typical concentration of water in the atmosphere, to a part per trillion, which is one molecule in 10 to the 12 molecules. That's an incredibly small amount. But yet, they do control the composition and chemistry of the atmosphere.

So the idea is that even though they're in such tiny quantities, they do make a difference to things. What sorts of things do they matter for?

There's all sorts of things. For instance, the ozone layer-- there are about 340 parts per million of ozone. And that protects us from harmful UV.

In the lower atmosphere, where we live, that ozone is very important for starting the chemistry that keeps the atmosphere clean. It cleans up all the compounds that we put in-- all the pollution that we put in.

We need to look at the whole atmosphere as one. I sometimes think of the atmosphere as a huge integrator of all the emissions from the surface of the chemistry between the molecules in the atmosphere and of the molecules coming down from higher up in the atmosphere affected by the sun. But there are boundaries in the atmosphere, also.

There's a boundary just above our heads-- maybe anywhere between a few hundred meters and one kilometer. It's why the air that we breathe-- the quality of the air-- matters immensely. It doesn't get moved about as easily.

Above that is what we would call the weather area, where we'd go up to the top of the clouds, we move chemicals around very quickly within that space. We see very different effects, according to the presence of clouds or not. And then we have the lid set on that weather system by the stratosphere-- the atmosphere beyond the stable atmosphere.

Now, that part of the atmosphere, interestingly enough, is not controlled by the sun or the earth. It's controlled by the presence of ozone. So just having a small number of molecules in that space creates a temperature gradient-- a barrier-- that stops us transporting easily molecules higher up and, indeed, molecules leaving the earth-- that have to fight gravity, of course-- but getting closer to that outer space boundary.

So quite interesting-- those boundaries that have been set throughout history and time still matter to us. But it's a delicate balance. And we can change those boundaries if we change the atmosphere too much.

If you ever get on an airplane, you noticed that it's raining when you get on the airplane. You take off, and you're above the clouds. Why is that?

Well, we live in what we call the boundary layer. The atmosphere is like a large fluid. And as it drags along the surface, it actually decouples that bottom layer. And if you think about it, 90% of the emissions of stuff that we put into the atmosphere is in that very bottom layer-- the planetary boundary layer.

So the idea is there's a sort of mixed layer because as wind goes on the surface, it's rough, and so it kind of mixes things up. And that's the bottom layer.

Yeah. That's the very bottom layer. But that's a sub-part of what we call the troposphere. Tropos comes from the Greek "to turn." It's the turbulent, mixed part of the atmosphere. And that extends away from the surface up to about the height of Mount Everest-- around 30,000 feet or eight kilometers or so.

Above that is the stratosphere. So actually, what you've got there is a cold layer that's sitting on the warm layer below. And that's home to the famous ozone layer. And that's very important for protecting us from harmful radiation for Earth.

As we go above that-- and now, actually, once you leave the stratosphere-- you're about 10 kilometers. You're about 90% of the mass of the atmosphere. You're into the ionosphere and the thermosphere, which is very, very low concentrations of gas and very large amounts of energy coming from the sun.

Atmospheric composition is something really fascinating. When thinking of the fact that now, we can observe air quality using satellites that are either 800 kilometers away or even we are thinking of geostationary instruments, which will be 36,000 kilometers away, I think it's fascinating. But at the same time, you realize that light that goes through the atmosphere-- so any satellite-- will have deal with atmospheric composition.

And it's actually no surprise that the first thing that the first satellite saw was the ozone layer because light was going through. So, of course, our eyesight is not dimensioned to see all the light is changed at different wavelengths that are affected by the gases and the aerosol in the atmosphere. But if our eyes were acute in different regions of the spectrum, we could see aerosols, we could see CO_2, we could see methane.

The atmosphere is, in fact, a big soup of different constituents. It's about several tens of thousands of species which are in the atmosphere. And their fate is almost the same for all--that is, emissions through different types of processes, human emissions, like from exhaust from cars, emissions from trees, et cetera. All these species go into the atmosphere, they are transported by winds. They follow chemical reactions.

You have molecules that react together. And then, basically, if they meet a cloud of precipitation, several of them will be deposited to the ground. And depending on their chemistry, they have a different lifetime in the atmosphere. And we see molecules that will stay only for less than a second in the atmosphere. And you see molecules or particles that will stay for weeks or even longer, with the greenhouse gases that can stay for hundreds of years.

Most of the atmospheric composition is not human-made. For certain specific species, the human contribution is very high, like, for instance, nitrogen dioxide, NO_2. But for all the species, like ozone, the human contribution is not so high. But the slight difference that is made by the human contribution can make a lot of difference. And it's the case, of course, for CO_2.