Topic 3a - Part 1: GHGs and climate change – how the data helps us understand the past and the future

Welcome to Week 3, which is called Large-Scale Changes, Ozone and Greenhouse Gases. We'll be looking at some of the changes to our atmosphere that humans have made, and things like the discovery of the ozone hole. I'll be looking at how atmospheric monitoring both helps guide policy, and helps enforce any regulations that are put in place.

Tell me what your job is.

I am a scientist, a Senior Scientist at the ECMWF. And my job is to work on modeling of CO2 using the capabilities we have here at the European Center to do weather forecasts. So that's essentially what I do. I improve the model to be able to simulate CO2 and methane, which are the two most important anthropogenic greenhouse gases in the models, so that then we can make use of observations to basically have the best picture of how CO2 and methane is varying both in time and space.

And CO2, so this carbon dioxide and methane are very-- they're gases that are of a huge amount of interest now, because we are putting more of them into the atmosphere. We humans as a species are changing the atmospheric composition with respect to those two gases. Tell me a little bit about what you see in the observations.

So the observations show clearly an increase. Every year we have global mean increasing. Specific observations also show variabilities associated, of course, with transport and with local fluxes. But globally, we see this increase.

And this is a net increase that is caused by the increase in emissions every year. We also make more CO2, mainly associated with fossil fuel use. But also, we see the signal of the vegetation and the ocean. And the combination of these gives you this increase, atmospheric growth in the atmosphere.

And what consequences does that have for humans and for the planet?

So the main consequences are, obviously, climate change. So CO2 and methane are the most important climate forcers. So greenhouse gases, they can trap the infrared radiation emitted by the Earth.

And so they are very important, because they can keep the temperature higher than it would be if we didn't have them. But obviously, if they increase, then the temperature can keep increasing, and can feed back itself on processes that are also responsible for emitting CO2-- for example, photosynthesis or organic matter decay. And so you can get old permafrost thawing. So you can get a feedback that can give you a very rapid drift in the climate equilibrium.

So we've got in front of us a beautifully detailed graphic of carbon dioxide observations. And many people are seeing the very famous Keeling curve, the dataset from Mauna Loa, where there's this annual cycle in carbon dioxide, but it's always going up. And what this is showing is that it's not just one number. So tell me a little bit about the difference between those two things.

Yes. So we have the increase, but that increase would give us the increase in the emissions. And if we just take this into account, we will get a much larger increase in the atmospheric CO_2 than what we observe. So obviously, there are also sinks that are associated with a CO_2 carbon cycle. And these things come from vegetation and from the ocean as well. So we have to represent this in the model if we want to get the right increase as observed, for example, from Mauna Loa.

And here, when the Pacific Ocean comes around, we can see that there's one spot in the Pacific Ocean. But the concentration of carbon dioxide is not the same all the way across the planet. And there's a very strong seasonal cycle. What is it that's driving all of this variation in the carbon dioxide in the atmosphere?

So vegetation is what is driving this variability short term. That's the main driver of the variability. And you can see, for example, the first thing we see is that there is a pulse, a daily pulse. And that's the diurnal cycle of vegetation.

So that's because when the sun comes out, then plants versus synthesize, take in carbon dioxide, and then at night when they respire, they give it out. So you're watching breathing.

Exactly. So that's the first process that we see on short time scales. Afterwards, then we see the weather patterns. So weather patterns are moving CO_2 from areas where it is produced or where it is taken away from the atmosphere. So you can see these anomalies moving around.

And then we also see that, of course, vegetation depends on the season. We see that in the winter, vegetation is sleeping. So the main process is respiration for the decomposition of organic matter in the soil. And then we see a net increase. And that's why we see these reds, kind of high CO_2 anomalies in the winter.

But in the summer, we have the opposite-- vegetation growth. There's photosynthesis taking CO_2 from the atmosphere. And then we see a dip, and we see the green colors, which means that CO_2 is below the global average.

And this changes depending on the season. And because the seasons are opposite in the different hemispheres, then we see this flip of colors with the season. So the inter-hemispheric gradient is generally that CO_2 is higher in the northern hemisphere because we have more emissions.

And that's enhanced in the winter. But in the summer, we see, actually, at some point we will see that this gradient is reversed. And we have lower concentrations in the northern hemisphere during the summer because of the effect of vegetation.

And so you've combined here a weather model with understanding of the physics, and the chemistry, and data inputs. And it's an immense-- it's a really detailed structure. So what you can see is that there's a natural cycle of the Earth breathing in and out.

And then there are emission sources that are contributing to that. And so you can, when you've got a model like this, you can see who's emitting, where the sinks are. And how is all of this changing over time? Can you say anything about that?

So over time, we can see mainly the global mean changing. But also, we see if there is, for example, a season where there are tropical cyclones. Then we would see different patterns associated with that.

Long-term, what we can see as well is that, for example, changes in vegetation cover or in permafrost would also change the emissions at the surface. Movements of people, so growth of cities-- that would also give a different emission, which would then also be reflected in the atmosphere as increased, or for example, decreased if you observe afforestation.

And how do you see these greenhouse gas-- these data products like this one, where in the future, we might be able to go and see today or yesterday or tomorrow where are the sources and sinks of these gases. How is that going to help us in the future? How is it going to change the way that our society does things?

In a way, we can be more aware that what we do has an impact on the atmosphere. And for CO2, this impact stays for many, many years. So it's very important to be aware of that.

Methane can be removed after a decade, but CO2 will stay. So we have to remember that CO2 has a very long memory, and that it then interacts with the climate. And it can actually have feedbacks that are very scary.

So the important thing is that it's not just that we put these gases into the atmosphere and they sit there, but they then change the system itself. So you put them up, and then they maybe reincorporated back into vegetation. But then they may get emitted in a different way. And it's all cycling around.

Exactly. And if this cycle, which usually has a balance, is broken, because we decide that we want to use carbon that has been buried for millions of years and release this carbon that has taken a long time to be stored immediately, then we break the equilibrium. And then it's very difficult to predict, actually, what's going to happen, because of the feedback with the climate.