Topic 4d - Monitoring biomass burning and validating wildfires

So we're in a greenhouse with lots of plants. And when we think about what's in the atmosphere, we think about what's up there. But a lot of that starts with what's down here, doesn't it? Tell me how the plants are influencing the atmosphere.

OK, so these plants are constantly absorbing CO2 from the atmosphere to make new plant material through photosynthesis. Roughly, this plant is about 50% carbon. And of course, it's nice and moist here in this kind of semi-tropical environment. But when these plants die, or the litter they produce onto the forest floor, that can actually dry out and is fairly combustible because it's 50% carbon. So if the material dries out sufficiently, this material can burn. And when it burns, most of that carbon is released into the atmosphere as carbon dioxide. But there are many other chemical species that are released in lesser quantities than that, and these can have quite significant effects on the atmosphere.

So what we've got here is a combination of a sink as carbon dioxide is being taken out. And then at some time later-- it doesn't have to be immediately-- you've then got a source giving back to the atmosphere. So carbon dioxide comes in, that's fine. That's how photosynthesis works. But then that source afterwards, what sorts of things can be given back to the atmosphere? Because it's different to what goes in.

So anyone who's seen any kind of combustion will know that you get smoke produced, and the visible part of that smoke is the particulates. So these are small particles, and indeed, they can actually be quite hazardous to health if they're in sufficient concentrations. So these are called PM 2.5 or PM 10 depending on their diameters. There's something called black carbon, which is small carbonaceous particles. And then the rest of the emissions are generally in the form of gases, as I say, most of which is CO2, but there's significant amounts of other compounds released like carbon monoxide, other carbonaceous compounds like methane, compounds containing nitrogen like nitrogen dioxide, et cetera.

And eventually most of that will become carbon dioxide again, but those other species have a strong influence on the atmosphere on the way. So methane, for example, is a strong greenhouse gas. And nitrogen dioxide has effects on the atmosphere. So this plant matter could all just decompose, right? Or it could burn. What's the difference between the effects on the atmosphere in those two cases?

So you get different chemical compounds released in smoke than you do through decomposition because it's a different process. Although it's is kind of a similar process, just radically speeded up. But you obviously have different temperatures, et cetera, involved. And also it's very, very fast. So for example, if you live downwind of an area where there is significant biomass burning, you'll probably find your air quality is significantly impacted by that. Whereas it probably isn't impacted at all by decomposition, essentially because in a very short amount of time you can convert huge amounts of plant material that may have taken

years or even decades to produce into mostly atmospheric species. So you can imagine all that going to the atmosphere at once, can have a really massive effect on the local atmosphere, and even the regional atmosphere if there's enough of it, and through long range transport, as well.

A forest fire to me sounds like a big dramatic bad thing, but actually they happen naturally, don't they? It's part of the cycle.

That's right. There's many environments on earth where fire is a very natural process. So for example, savannas, boreal forests. These have regular fire regimes of different return intervals. So fire is very, very frequent in savannas, less frequent in any particular place in boreal forests, for example. But there's fire in all of them. But there's other environments like tropical forests, for example, contains similar parts to what we might see here. They're kind of fire resistant environments. Fire's a bit of an alien thing in those environments.

But because humans are modifying these tropical forests through deforestation, through draining peat lands, et cetera, they can become very combustible. And in the case of tropical peat lands, for example, there's meters of carbon rich organic soil that when it's dried out through draining and drought is almost like a huge landscape that is essentially like a fire lighter that's very, very combustible and very, very damaging if it actually ignites.

So then you've got a very sudden, very large source of stuff to the atmosphere coming up from below.

Exactly. And in that case, the fire can actually percolate into the soil and be burning underground. So it's actually very difficult to put it out. It can burn down into the ground as well as across the ground, so it can burn in any one place for days potentially, or even weeks. And it burns in a fashion that's very smoldering rather than flaming, and typically smoldering combustion produces more of these non-CO2 products. So they're the ones that cause most of the air pollution.

Paint me a picture of a forest fire.

So it very much depends on what kind of ecosystem you're in. Fires behave differently in different types of biomes. So you might naturally think of tall trees engulfed in flames as the kind of typical wildfire, but here we've got a photograph of one of the biggest fires on earth, in fact, which occur in tropical peat lands of Southeast Asia during droughts. This area would have been quite fire resistant naturally. It would have been covered in tropical forest and wet for most of the year. But as you can see here, the forest has been cleared away. The peat lands have been drained by building these large canal systems to remove the water essentially so you can grow crops on these areas.

But that's also made them much drier. And during droughts, all this material here, which is

about 50% carbon, can actually dry out, and if ignited by other fires in the local area, can actually ignite and burn. And you can see here there's no flames at all being seen. What's happened here is that the soil itself essentially, the peat, is actually burning in a kind of smoldering way below the surface and just releasing all this smoke through cracks and gaps in the surface into the atmosphere.

And what sort of area was this-- when this picture was taken, what sort of area was that happening over?

This would have been huge areas of Southeast Asia. In these extreme fires that occur during El Nino related droughts, you could burn more than 10,000 square kilometers, for example, in a single country, which is absolutely enormous. And that would take place maybe over a couple of months.

And these are seasonal, they are? They happen at some times of year?

Vegetation fires across the globe are generally driven by the seasons. So if you look at fires in Africa, for example, they'll occur in North Africa in one part of a year and then migrate to southern Africa in the other part of the year. Fires in this kind of environment are certainly seasonal like that, but they have huge changes between years basically because they're driven by lack of rainfall in parts. So they will only occur in really massive quantities when rainfall is absent for a period, which only occurs every few years.

And we can see here very clearly that stuff is being given off as everything burns. How would you monitor that? I mean, no one wants to go in there, right? How would you get at what's going on?

So we had a field campaign to this environment in 2015, and we took a large amount of equipment to measure the chemical species and the different particulate matter that's present in the smoke. And we can do that on the ground, but also as you say we can't really get really deep into some of these environments. So we went off, and essentially built this drone here where we fitted that with thermal imaging cameras so we could see the kind of temperature of these fires that are different in these type of fires because they're burning underground. And also we had some sensors on here to measure the concentration, for example, CO2 and carbon monoxide that's in the actual smoke, which tells us something about the nature of the burning.

You can see everyone here has got masks on because for humans this is not a safe place to be, but the drone can go up above, can go where the humans can't go. But then you have measurements absolutely in situ just above the fires, which must provide a huge amount of information.

Yeah, that's right. So the concentrations of particulate matter here, for example, were 10

times what you would normally consider extremely hazardous. That's why we're wearing all these masks. But basically the drone and the associated equipment is not really affected by that. So we could fly this, do profiles, for example, of aerosol concentrations and all sorts of things that would be very difficult to do by hand.

And not every country has lots of wildfires. Where do they tend to occur and which others have you studied?

So this is in Southeast Asia in this particular environment where you have this set of conditions that really has made the whole place very fire-prone. Other parts of Asia, for example, we have deforestation fires. Lots of agricultural burning that's associated with farming, essentially removing material that is not being used for other purposes before the next harvest.

In Africa you have the largest burn areas on the planet, which is basically in the savannas of Africa, which burn very, very frequently. Maybe every couple of years a particular area will burn again. And then in places like Canada and the boreal forests of Russia, they have fire as part of their natural ecosystem process, but not so short a return period as it is in the savannas. So you might have 50, 100 year type return periods for fires in those kind of boreal forest environments.

And what are the consequences for air quality? Because obviously this is-- it doesn't look good, right? But globally what are the consequences for air quality?

So of course if you live relatively close to a fire, then you're going to be heavily impacted by smoke. And the main issue is the particulate matter in the fires. Because that can reach quite high concentrations in the smoke, and that smoke can be transported quite far downwind. And these particles are very fine, so they can stay lofted in the atmosphere for quite a long time.

So in Canada, for example, occasionally there may be evacuations of towns because of fires actually moving close to towns. But mostly evacuations are actually associated with air quality problems. In places like this in Southeast Asia, these fires was of such a huge magnitude that the air quality impact was regional, not just local. So countries quite far away from where the fires were themselves were quite seriously affected.

And how does the weather affect the air quality-- the range, if you like, that a fire can affect? Because if the wind changes direction, or there might be weather systems that make fires more likely. How do weather and the air quality interact?

Fires typically occur obviously when it's warm, dry conditions. In fact, fires are partly driven by wind. So wind actually promotes fire and will generally make the intensity of the fire much greater than if it was a still day. But wind also allows the smoke to be transported greater

distances. Things like rain will not only put out fires, it will wash stuff out of the atmosphere. So obviously the meteorological conditions are quite important both in driving fires and understanding what happens to the pollutants that they emit.

And what's the predictive capabilities? Here you can see people on the ground. The fire's already started and you can't do anything about that, really. But presumably people could take action. Or if you knew that this was likely to happen, you could start evacuations early. So what sort of predictive capability do you have for seeing these things coming in advance?

So it's very hard to predict exactly when and where a fire will occur, but you can quite successfully predict the type of landscape conditions that are conducive to fires. You can't say that a fire will definitely occur at this place, but you can say, well, now the landscape is in a flammable situation. And if there is an ignition there, the fire can take hold and spread.

And so the Canadian Forest Service are some of the best people doing this kind of thing because they have a huge forest and a huge forestry sector. And so they have developed over many decades the capability to forecast the flammability of the landscape, essentially, from meteorological variables. And that system, it's called the fire weather index system. That's been kind of exported to other countries around the world, including in Southeast Asia like we saw there where essentially short and medium term weather forecasts are used to drive predictions of where the landscape may be flammable enough to burn. And so you can preposition resources there in case fires occur.