Topic 2g - Land: in-depth case study - measuring biomass

A lot of the areas that we're concerned about with respect to climate change, like Arctic environments or tropical rainforests, are really difficult to reach in the field. And we have some good data from site-level studies that people have done on things like biomass, and soil carbon, and things like that. Remote sensing can help us to get a landscape perspective, a regional perspective, a global perspective, on how much biomass is present in these systems, and how that's changing over time.

So there were ways of inferring that before, but what remote sensing does is gives us a consistent method across the entire globe, so we can compare regions with each other and reduces the uncertainty of that. So we call that type of analysis a scaling process. We take information that we have at the plot level, and we apply it to the entire globe.

So in some cases, we've got trees that we've actually cut down and measured how much carbon is in these trees. If we have a forest canopy of this height, how much biomass does that mean in terms of what we see on the ground? What remote sensing tells us is how high is the canopy throughout the whole forest? And then we can tell you, for any given spot that we couldn't possibly visit on the ground without enormous expense and difficulty, how much biomass is there.

Here we are in a piece of rather classic English deciduous woodland. And this illustrates very clearly some of the problems and challenges that we have in trying to use satellite data to measure and understand a system like this. One of things that we can see very clearly is the layering of the canopy. So we can see branches at different layers in the canopy, and different densities of leaves. We can start to see the leaves changing colour.

Most of all, you can see the variation in the light levels in the canopy. So the sunlight is arriving at the top of the canopy and is passing through. And we have these multiple different layers which are absorbing the solar radiation on its way down, scattering from leaf to leaf, and from layer to layer.

If we look more widely across this area of woodland, we can see a kind of mixed environment with some beech trees, and there are birch trees, and there are oaks. And there's an understory, and there are grasses, and flowering plants. So even within this very small area behind me, there's a very, very wide range of vegetation, even if we just count the trees in there.

So one of the challenges we have is trying to understand from a signal that we've measured from hundreds of kilometres away out in space, what is here? We can see the complexity of the canopy system. We have thousands and tens of thousands of millions of leaves all sitting here capturing sunlight.

Some of that light is then reflected, and that reflected light is the signal that we get to measure from satellite data. So what we'd like to be able to infer is things like how much leaf area there is on a unit area of ground. It's what we call leaf area index. In order to derive estimates of leaf area, we need accurate models that are able to simulate what the radiation regime is in a canopy like this.

As the summer turns to autumn, and the leaves start to brown, the trees are taking what they can back out of the leaves, taking the pigments, and returning them to the tree to save for next year. And we can see that change very clearly from space. That's something that's very visible, and it gives us a signal that tells us how quickly these trees are changing, how quickly they're dropping their leaves.

So over the past 10 or 15 years, our ability to model that kind of signal has improved dramatically as we understand more about what these systems look like from space. The types of sensors and the types of observations that we have and, in turn, the models have had to get better.

We also have to be able to say how good our models are and how good our observations are. This comes back to this process of a validation. And one of the key ways we do validation of satellite data is by doing ground field measurements. And that involves going into places like this and measuring the structural properties of how much leaf material there is. And also measuring the biochemical properties, measuring the chlorophyll and nitrogen and phosphorus content of the leaves. So this kind of system is used across the world and in the tropics as well, and in the temperate regions, where we can put instruments. And we can put people at various different levels within the canopy.

So when we want to measure things like leaf area through the canopy, and we want to measure things like leaf biochemistry through the canopy, we have to be able to get access to the different parts of it. Because if we think about the remote sensing signal, again, typically what we're seeing is the stuff that's coming out of the top. The stuff that's coming out of the top, the reflected radiation, is a function of everything that's going on underneath here.

Not only is it to do with measuring leaf area, and leaf biochemistry, the types of measurement that go on here are things like measuring carbon dioxide fluxes. What that allows us to do, is it allows us to measure accurately at the kind of plot-level scale, how much carbon this system here is absorbing.

So in order to validate those satellite estimates of gross and net primary productivity, we put towers in the forest that measure the amount of CO_2 that's being absorbed by the forest over time. And that allows us to build up a living, breathing picture of how much carbon is being absorbed by this system.

The time frames over which we're able to make observations from satellite, those satellite observations we have over the last 10 or 15 or 20 years, or so, give us a relatively recent snapshot. Now the challenge is to integrate that with our understanding of why these systems look the way they do over the last few hundred years, and how they're likely to respond to changes that are going to be quite rapid in terms of human impacts, and in terms of climate impacts. Those are going to be quite rapid changes in the context of what has happened to these systems over the last hundreds and even thousands of years.

This shows three dimensional data that we captured using a laser scanner on the ground. So this is not really a remote sensing measurement. This is a measurement-- that is related to remote sensing in some way. And what we're trying to do here is we're trying to capture the structure and amount of stuff that's here in this one hectare plot in Gabon, and then use our knowledge of that. Now having made these measurements, we have a very, very detailed understanding of how many trees there are in this plot, how large those trees are, and how much leaf area there is, and so on.

So when we're trying to understand what is happening to tropical forests, for example, in this case, the things we need to know is how much biomass is there now. How much carbon is stored in these trees, and how that carbon storage is likely to change over time? How is it likely to respond to things like drought and to changes in temperature, precipitation, and wind, and so on, over the coming decades? So this kind of combination of field scale measurement with the satellite data is what is needed in terms of, first of all, extrapolating the field data out to much, much wider areas, but also in terms of understanding the uncertainty in the satellite data products.

So these particular measurements were made using a terrestrial laser scanner, or LiDAR scanner. So LiDAR is a technology that fires out laser beams and essentially measures the distance that that laser beam reaches before it hits something, and then the energy's returned back to the sensor. So LiDAR is a kind of technology that's been widely used for a range of different applications. It is, in essence, a remote sensing measurement. It's been widely used in the past for things like surveying applications, for measuring distance very accurately.

LiDAR is now being more and more widely used in remote sensing applications for measuring things like canopy height and for measuring digital elevation, so measuring the changes in elevation of the earth's surface, because it can measure it very precisely over large areas. And LiDAR is increasingly being seen as a tool for doing measurements of this sort from space. So there have been proposals in the past for space-borne LiDAR instruments for doing canopy measurements.

There have been a couple of LiDARs launched into space, one of which was a NASA instrument for looking at ice sheet dynamics and sea ice. And there is a proposal that looks as if we're going to get a canopy LiDAR in around 2020, launched on board the International Space Station, called Gedi. That will also allow us to combine with new radar instruments.

So for example, one of the new ESA Earth explorer missions is the biomass mission, which will be doing a similar kind of thing, but at radar wavelengths. And so having this multiple radar, LiDAR, and ground-based observation capability is what is really going to allow us to unpick the subtleties of the changes of a forest structure and dynamics in the forthcoming decades.