Image of Harwood Forest reproduced by kind permission of Rick Ford

Lumps and bumps

Mathias Disney describes how a lightweight laser scanner has been put to work to measure small-scale topography in a forest setting - and further our knowledge of greenhouse gas emissions

The UK is committed to measuring and managing its emissions of greenhouse gases (GHGs) to counter the threat of dangerous climate change. To do this we need to know the rate at which gases, particularly carbon dioxide (CO_2), methane (CH_4), and others such as nitrous oxide (N_2O), are emitted and absorbed by the landscape. So how do we do it?

It's relatively easy to quantify man-made GHG fluxes because we can look at consumption and production figures for transport, industry etc., and infer the totals quite accurately. Estimating biogenic fluxes, i.e., those pertaining to plants and soils, agriculture, forestry etc., is much more difficult. As we all know, plants absorb carbon dioxide (CO_2) during photosynthesis and emit oxygen (O_2). But, like us, plants also emit CO_2 during respiration. They also maintain complex relationships with microbes and fungi in the soil that process nutrients, decompose dead plant matter turning it back into carbon in the soil, producing CH_4 and N_2O along the way.

Sinks and sources of biogenic GHGs vary hugely in space and time across Britain because of the 'patchwork quilt' nature of our managed and semi-natural ecosystems. These fluxes are highly dependent on the type of vegetation (crops, forests etc.), soil type and climate. In addition, the various GHGs respond differently to meteorology and management; soil moisture, for example, has a huge impact on CH_4 emissions. So understanding how these biogenic GHG emissions vary in space and time is key to developing accurate inventories that allow us to understand the current emissions, and the feedbacks between climate, land use and management.

Into the GREENHOUSE

The UK government, largely through the Natural Environment Research Council (NERC), is funding research into characterising GHGs from the land, ocean and atmosphere. One such project, a part of which is led by the author, has the clever if rather verbose acronym of GREENHOUSE (Generating Regional Emissions Estimates with a Novel Hierarchy of Observations and Upscaled Simulation Experiments).

GREENHOUSE is a consortium of researchers, led by Prof. Mat Williams at the University of Edinburgh, the aim of which is to estimate Britain's biogenic GHG emissions using a wide range and scale of measurements. For example, small automated chambers measure GHGs at the centimetre-to-metre scale on the ground. Another method employs so-called flux towers that stand tens of metres above crops and forests and 'sniff' GHG concentrations in the air very accurately every 30 seconds or so. Satellite observations also tell us how crops and forest vary seasonally and in space from year to year at the national scale. All these observations are fed into models that allow us to probe what happens when the climate and

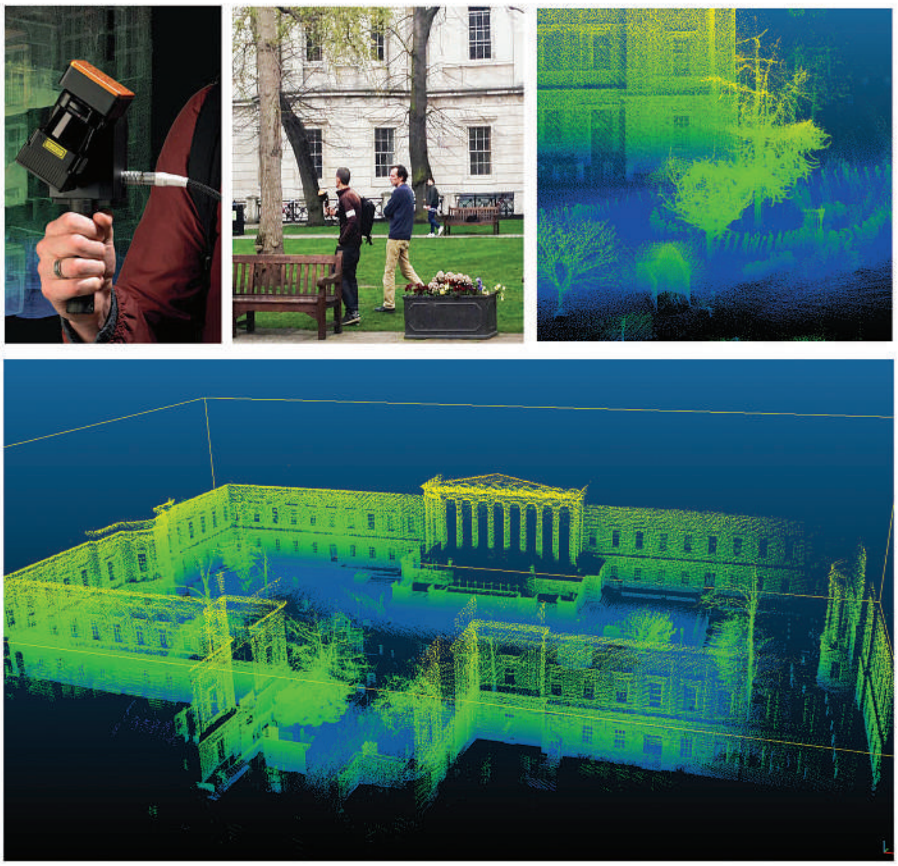

Fig.1: the ZEB-Revo laser scanner (top left). Top centre: the author and a colleague walk the main quad at UCL with the ZEB-Revo (image: Ewan Shilland). Top right: the resulting 3D data. Lower image: wider 3D view of UCL quad (image: Phil Wilkes)

Fig.2: A clear-fell area of Harwood forest mechanically harvested of trees

management change.

As part of the GREENHOUSE project, postdoctoral researchers Phil Wilkes and Andy Burt, plus MSc. student Darcy Glenn, all at University College London (UCL), recently visited Harwood Forest in Northumberland to trial a newly-acquired ZEB-Revo lightweight revolving laser scanner from GeoSLAM.

Harwood is a Sitka Spruce plantation forest, managed by Forest Research primarily for commercial use. As such it is not a natural system, but is typical of much of the current UK forestry. When the forest is harvested for timber, large areas of scrub are left, which decompose quite slowly, releasing CO_2 and CH_4, methane. CH_4 is a very potent GHG, with more than 20 times the warming potential of CO_2, and is extremely dependent on the soil moisture – the more saturated the soil is, the more CH_4 is released by microbial decomposition. The soil moisture is in turn very dependent on microtopography – the bumps and hummocks across the surface that tend to create pools of water. The team was keen to use the ZEB-Revo to try and measure this microtopography at Harwood. An initial sortie conducted at UCL left a favourable impression of its speed and ease of use (Fig.1).

Walking the walk

Having arrived at Harwood, a slow walking pattern was adopted in scanning the site to derive a Digital Elevation Model (DEM), accurate to a few centimetres in height. Being able to generate an accurate DEM like this means that colleagues can much more accurately measure CH_4 fluxes at fine scales. This, in turn, builds an accurate picture of how activities such as planting and harvesting change the CH_4 budget of a forest like Harwood.

Fig.2 shows a clear-fell area at Harwood – a part of the forest that has been mechanically harvested of trees in the last couple of years. The remaining ‘brash’ (waste wood, bark, stumps and branches) is obvious. This brash is decomposed by bacteria to produce CH_4, and measuring emissions from these areas is key to accurately calculating GHG emissions.

In the past, such emissions have been ignored completely or estimated very roughly, leading to large unexplained errors that tend to pop up in model and data analysis. It is also evident from Fig.2 that the

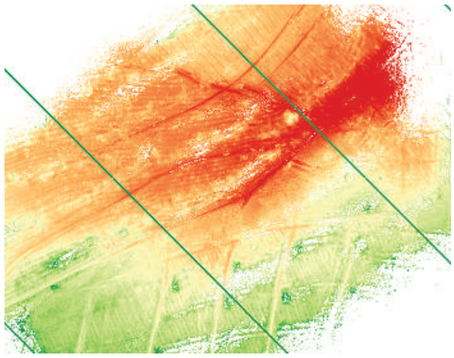

Fig.3: First DEM derived from ZEB-Revo scans acquired at Harwood

topography varies hugely on small scales. The ZEB-Revo has proved ideal for measuring this variation very accurately and quickly, allowing us to build a centimetre-accurate DEM over hundreds of square metres in a couple of hours-worth of scanning.

Fig.3 is the first DEM produced across the Harwood site from the ZEB-Revo, with green to red representing height from low to high values. The site drops slowly from bottom to top, and the small river valley is clear on the upper right. The artificial ridges produced by planting are also evident in the lower part of the image. This sort of detail is fundamental in getting the CH_4 budget right, but would be extremely difficult and time-consuming (if not impossible) to measure in any other way than with a small, portable Terrestrial Laser Scanner such as the ZEB-Revo. The fact that the task can be accomplished quickly and by a single person is revolutionising our ability to build such fine-scale DEMs.

The first results from this research are already providing vital information to colleagues in estimating CH_4 fluxes at Harwood. Over the next year, other sites across the UK and further afield will be visited to help us build an even more accurate picture of GHGs.

Acknowledgments

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