# Live from a landfill

**What's so hard about putting a number on greenhouse-gas emissions? Grant Allen describes some distinctly unglamorous fieldwork aimed at doing just that.**

My research into greenhouse gas (GHG) emissions often takes me to pleasant and exotic places – the Arctic, Australia or Chile, to name a few. But in August 2014, I was part of a large contingent of the UK's leading atmospheric scientists, who descended on a Viridor landfill site in eastern England for a two-week measurement campaign in an attempt to gauge precisely how much biogenic methane was being emitted to the atmosphere (known as 'fugitive emissions').

Why two weeks? Why a landfill site? And why should it take so many experts, I hear you ask? These are all good questions. And they all concern a surprisingly common problem facing atmospheric scientists – how can we measure the exchange of trace gases between the Earth's surface and the atmosphere – also known as quantifying flux?

An enormous global scientific effort has been, and is still being, devoted to combining measurement and modelling techniques to provide accurate fluxes. The problem is that no one method is perfect, and studies over the decades have failed to make the results of different techniques match up.

This is particularly difficult when we're trying to scale up our results – that is, to extrapolate from measurements taken at particular places to get statistics that accurately represent whole regions. We have no problem measuring the concentration of a gas, but this is not the same thing as measuring its flux. And it is the physical processes that control the mixing and chemistry of gases emitted into the atmosphere that make determining flux so difficult.

This problem is especially pertinent in trying to understand GHG emissions and air quality – both important subjects for society as a whole. In the case of global warming, accurately predicting climate change relies on knowing the concentrations of GHGs, and their chemistry and transport, in the atmosphere.

The most important part of this is understanding the sources and sinks of such gases – in other words, where on Earth they will be emitted and absorbed in the future. But the first step to getting that right is to know what is going on today, by measuring and understanding the physical processes – both man-made and natural – that add up to create the well-known rising trends in global GHG concentrations – especially carbon dioxide, methane and nitrous oxide.

Current estimates of man-made GHG emissions come from what are known as 'bottom-up' techniques. We make informed guesses at the emissions coming from individual source-types, such as vehicle emissions or agriculture, scale them up according to how common these source types are – usually within national boundaries

*The world's first drone-based in-situ precision measurement of $CO_2$ concentrations.*

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*Automatic flux chambers on the slope of a hill of capped refuse.*

– and then add them together to provide an overall emissions inventory.

Few would question that these bottom-up inventories are far from accurate. But we're not sure exactly how inaccurate they are, and this is what attracts scientists, policymakers and regulators to the problem – no one likes a number without an error bar – that is, an indication of how uncertain it is – and nor should they! Therefore, international governments, obliged by treaties to reduce GHG emissions, have recently commissioned scientists to perform what are known as 'top-down' studies. These are essentially measurement-led attempts to confirm the bottom-up inventories.

## Taking it from the top

In creating them, science is tasked for the first time with placing an error bar on emissions. And it just so happens that landfill sites are a perfect place to test many of the measurement and modelling techniques we use in top-down approaches, especially when dealing with so-called 'hotspots' – places whose emissions are strong and concentrated, but spread over an area rather than coming from a single point like a chimney stack, for example.

Landfills produce methane and $CO_2$, among many other very odorous fumes that I can promise you are in the air! These gases are released when microbes break down organic matter buried in the soil anaerobically (that is, in a low oxygen environment). Modern landfill operators typically cap areas of their sites once they've been filled with rubbish, capture this gas and burn it to generate electricity. But it's hard to collect all the methane, and a small (but significant) amount still finds its way into the atmosphere.

This is important for the climate, as methane is 23 times more potent (molecule for molecule) as a GHG than carbon dioxide. Although it has a much shorter lifetime in the atmosphere, its global mean concentration is increasing fast, and this is a cause for concern – especially because scientists aren't sure where it's coming from. I should point out that I don't for a second believe landfills are solely to blame! But they provide an excellent natural laboratory to test and improve our methods for measuring flux in other environments.

So, in August 2014 a team of over 30 scientists joined forces with practitioners from industry and the Environment Agency to test all the various approaches to measuring flux known to modern science. These range from instruments on towers to ground-based sensors and promising approaches where we release a set quantity of a proxy gas such as acetylene that we can measure offsite as it gets diluted in the atmosphere. These were complemented by measurements at a farm several kilometres away downwind that continued for two months, allowing us to study how the emissions varied in time.

We also conducted the first trials of using drone aircraft for automated measurements and 3D sampling over a wide area – an exciting new technology that the Environment Agency is working with me to develop for regulatory use.

We took precise measurements of concentrations of not only $CO_2$ and methane, but also carbon-13 isotopes, ozone and many other trace gases. We'll use these to calculate fluxes using each of these independent methods. We will then compare and examine them to find out which ones work best and should be used in future.

We will be asking several questions of our data. Are measurements at one location (or set of locations) truly representative of the whole wider area, and therefore scalable? Are instruments on flux towers affected by strong local variations in emissions? Do the proxy gas release methods we tested still work in turbulent windy conditions? And can drone sampling map the plume of methane in 3D?

Our conclusions will contribute to setting measurement strategies in all sorts of other places where GHG fluxes are important – from Arctic wetlands and oil refineries to shale gas operations, cattle farms and even mud volcanoes! In practice we will never be able to measure everything all the time, but this study will help reveal how much effort and sampling is needed to distil a useful narrative on national GHG emissions and how to monitor them.

Such measurement may then allow government to target sensible and measurable emissions reductions policies and even help industries to save money, for example by trapping more methane in the case of landfills, or by finding and fixing leaks for oil and gas companies. But measure we must. Just a shame you have to be surrounded by rubbish to make it happen…

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The landfill fieldwork involved researchers from the universities of Manchester, Cambridge, Southampton, Royal Holloway, Bristol, Edinburgh, and the Technical University of Denmark, as well as practitioners from Ground Gas Solutions and the Environment Agency.