arrangements in place for cover, while some left it to the individual to make arrangements, and others dealt with it informally, reallocating responsibilities to others in their group. The best practice was where departments received a budget from the university for cover from sessional lecturers either during the maternity leave or for the period just after maternity leave, and where the arrangement was discussed in advance.

There were examples of good practice to support returners. One university had produced a good practice document on maternity returners. A number of departments work with individuals to ensure that they are given support. In one case staff were encouraged to meet with their line managers, as well as the head of department, before their return to discuss arrangements. In another case individuals taking parental leave were expected to have a staff development review on their return. There were examples of returning staff being given time to readjust to the workplace and to catch up with research through, for example, being given a term's grace from teaching responsibilities or being granted a period of study leave immediately following a period of maternity or adoption leave. Some departments also had in place arrangements to monitor returners on an ongoing basis. In one example during the phased return period the head of department met the member of staff weekly, to assess progress and identify any problems and to discuss future career progression. A number of departments also encouraged returners to take up flexible working arrangements.

The LMS hopes that by disseminating and highlighting the best working practices currently in place in mathematics departments, all departments will be encouraged to learn from the best and in doing so improve the position of women in mathematics.

References

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METHANE: THE UNNATURAL GAS

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Methane (commonly known as "natural" gas) is one of the major greenhouse gases (GHGs) recognised by the Intergovernmental Panel on Climate Change (IPCC). Molecule-for-molecule, methane (CH_4) is 23 times more potent than CO_2 and it accounts for ~7% of all GHG emissions in the UK (in 2009). Luckily, there is much less CH_4 in the atmosphere (on average) than there is CO_2 – about 200 times less. However, although the absolute concentration of CH_4 is currently relatively small, its potency means that even a small change in the total amount of methane in the atmosphere could be comparable to the global-warming impact of its more well-known counterpart. Just as importantly, CH_4 changes the way in which the atmosphere can naturally cleanse itself of pollutants, which can result in poorer air quality. Such changes could be under way.

One thing is certain – the atmosphere is (and always has been) changing. This change has historically been the result of natural perturbations, often (but not always) over long timescales. However, in recent history, mankind has been speeding up this pace of change with uncertain consequences. Whilst the general premise that climate-change-equals-global-warming is widely publicised, the more localised and extreme impacts implicit to climate change are often missed. For the UK alone, these impacts are thought to be more frequent extremes in weather of all types, hot and cold, dry and wet, windy and stagnant. This is because we are an island in the middle of the North Atlantic storm track – where energy is often racing fast from the equator to the poles. While no single weather event can ever be directly attributed to climate change (by virtue of the way climate and weather are necessarily treated differently within mathematical models), we rely on statistics over long timescales. The number of weather records broken in the UK over the past 7 years (and in 2012 alone) should not be forgotten, nor should similar statistics reported around the world. Whilst still the subject of debate, a growing number of meteorologists and climatologists are beginning to talk about climate change as something that has been having a growing impact on our weather (and our lives and economies) for many years.

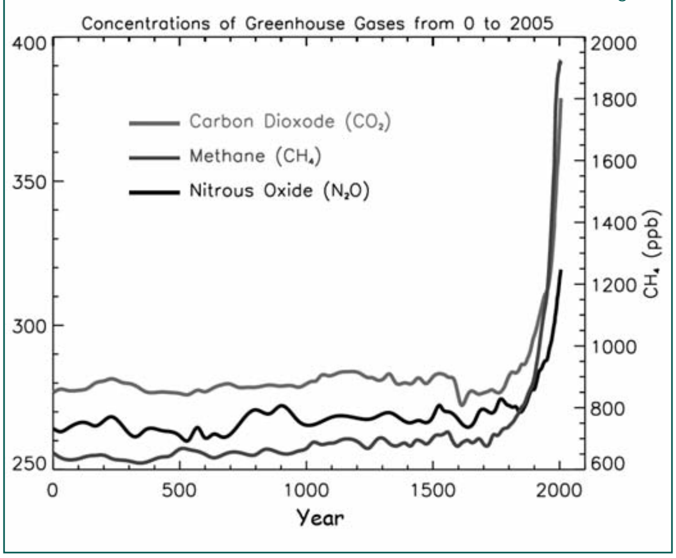
The principal driver of climate change is an increased greenhouse effect driven by increases in the amount of GHGs in the atmosphere, which trap infrared radiation (heat energy) near the Earth's surface. Various feedback processes, tipping points and buffers are known (or thought) to exist, which may exacerbate or limit changes in surface temperature (eg cloudiness, ice cover), yet the underlying response of the

. . . speeding up this pace of change . . .

atmosphere can be linked to the concentration of GHGs. Monitoring (and predicting) the concentration of GHGs in the atmosphere and how they are changing is therefore key to understanding the global (and local) consequences of climate change. While much successful effort has been put into better global monitoring of GHG concentrations in the atmosphere (eg through the WMO-led Global Atmospheric Watch programme and EU-led Integrated Carbon Observing System), the various sources and sinks of these gases remain the subject of study which bridges the many academic disciplines required to understand the Earth system. These include branches of physics, chemistry, biology and geology – all of which are required to assess how GHGs are emitted and/or deposited into the atmosphere from their various reservoirs (land, biosphere, ocean and the deep earth). Once in the atmosphere, we need to know how they evolve chemically as they are transported on the wind all around the planet. Furthermore, to make longer-term forecasts and attempt to mitigate changes in the future, we must also include sociology, economics and engineering. This is because the Earth's atmosphere (and its composition) is a dynamic system driven by different processes on different temporal and spatial scales. To make matters even more complex, local monitoring alone cannot address remote inputs and impacts. This interdisciplinary activity must be coordinated internationally. Much progress has been made but more still needs to be done.

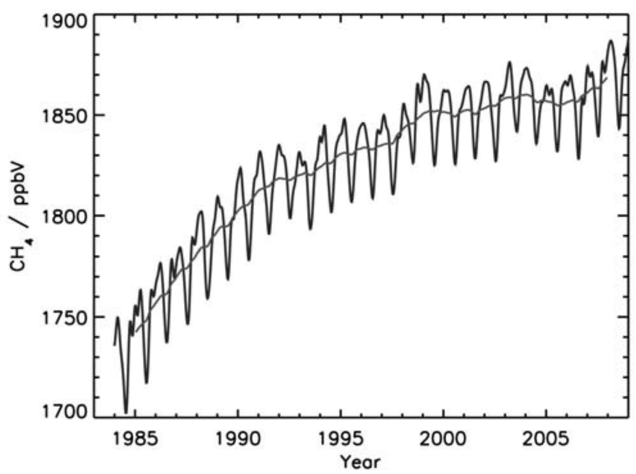
Whilst much press is given to the rise of CO_2 in the atmosphere, the sources and sinks of CH_4 are less well

Fig 1



Atmospheric concentrations of important long-lived greenhouse gases over the last 2,000 years. Concentration units are parts per million (ppm) or parts per billion (ppb), indicating the number of molecules of the greenhouse gas per million or billion air molecules, respectively, in an atmospheric sample. Source: The Fourth Assessment Report of The Intergovernmental Panel on Climate Change, Chapter 2, FAQ 2.1, Figure 1. The source of this image is a PDF file that can be downloaded at http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter2.pdf

Fig 2



Atmospheric methane concentration measured at Ocean Station M, Norway, between 1983 and 2009. Figure created using public archive data from the Cooperative Atmospheric Data Integration Project – Methane, NOAA ESRL, Boulder, Colorado; available via FTP to ftp.cmdl.noaa.gov

understood. What we know is that CH_4 is on the rise. Figure 1 shows ice core data from Antarctica, which can be used to track globally averaged CH_4 concentration in the atmosphere. What we see is a general pattern of a steep and accelerating rise in concentration since the industrial big bang at around 1800 AD, which continues to the present. This pattern is typical of many of the gases in the atmosphere that can be traced to manmade (anthropogenic) activity, whether directly or indirectly. With the benefit of plurality and accuracy of modern measurement techniques, we now know that within this upward trend, there are significant and sudden changes in global average CH_4, as well as seasonal cycles and other modes of variability (see Figure 2). It is the subtlety within these modes of variability and their potential causes (and uncertainties) that are the source of much important scientific effort. This article highlights this and also the work that remains to be done.

Among the sources of atmospheric CH_4 are many so-called natural ones. These include geological seepage of fossil-CH_4, anaerobic microbial activity in the near-surface, and animals. However, these are dwarfed by the various "unnatural" sources that can be linked to human activity, which include livestock, agriculture, fossil fuel burning and direct emission from natural gas exploration (and lines of transmission). As we can see from Figure 1, the concentration of methane has more than doubled since pre-industrial times. Furthermore, new additional sources of CH_4, which are being driven by climate change, are a key cause for concern. Chief among these is the unquantified release of CH_4 trapped in frozen methane hydrates in the permafrosts and ice of the Arctic and sub-Arctic (see "Arctic Methane Emergency" in SiP Spring 2012). Together with rising Arctic temperatures and increasing microbial activity in Arctic tundra, emissions in the area are hypothesized as one of the contributory causes of sudden increases in global methane seen in Figure 2 in recent years. Other contributing sources are thought to be the continued reliance on fossil fuels for energy generation, particularly in rapidly growing nations and the recent growth in natural gas exploration and transmission lines.

. . . increasing microbial activity . . .

We should recognise the world-class research by the UK academic community in this important area, enabled by funding through the Natural Environment Research Council (NERC) and DECC. Recently, the NERC Arctic programme has funded a number of projects that will tackle Arctic change and the issue of methane emissions in the region. Chief among these, a consortium of UK universities and international partners led by Prof John Pyle of the University of Cambridge, entitled Methane in the Arctic: Measurement and Modelling (MAMM), is currently investigating local and remote impacts of methane in the Arctic by studying the land surface and atmosphere over an area from Sweden and Finland to Svalbard. I am the coordinator of an aircraft-based study with the UK's Facility for Airborne Atmospheric Measurement (FAAM), which can measure GHG concentrations with unprecedented sensitivity while mapping wide areas. Early data show that the wetlands of Finland represent an important source of methane locally, whilst methane over the ocean can be dominated by a mix of signals both local and remote (with inputs from forest fires as far away as Canada). Further field campaigns throughout 2013 will help to place these data in both a wider and seasonal context such that regional emissions estimates may be extrapolated and used to improve models of how climate change takes place.

. . . largest source of CH4 remains anthropogenic . . .

Given the importance of the role of CH_4 in climate change, and in recognition of the fact that the largest source of CH_4 remains anthropogenic and can therefore be controlled, the UK Government is committed to reducing methane emissions under the Kyoto Protocol as one of a basket of four compounds (the others being CO_2, N_2O and SF_6). To meet these targets, the UK must reduce total carbon emissions by 12.5% (when averaged over the period 2008-2012) versus 1990 emissions. Currently, the UK is performing extremely well in meeting those targets, with total carbon emissions down by 29.6% (excluding emissions trading) by this measure in 2011 (DECC, 2012). This is significantly better than the EU-15 member group, which achieved an average reduction of just over 10% over the same period. However, although significant reductions have been made since 1990, these have been largely fortuitous due in part to a decline in the UK coal industry, and improved landfilling technologies (Methane UK – Environmental Change Institute, Oxford University).

The method by which these figures are calculated is far from ideal and relies on a bottom-up approach of summing a large number of emissions reports and estimates (often compiled within industries with vested interests), rather than hard measurement and direct attribution. To validate (and improve on) this approach, we must compare these emissions estimates with those derived using a top-down approach, where direct measurement is employed to attribute better emissions sources at high spatial resolution. This is critical to providing accurate emissions data under our regulatory obligations and to the economics of any future emissions trading schemes. To this end, NERC have recently commissioned the Greenhouse Gases: Emissions and Feedbacks programme, which has funded three national academic consortia to investigate this

. . . measurements in flights around the UK . . .

problem from both sides, with the ultimate aim of better constraining and predicting UK GHG emissions. One of these consortia, the Greenhouse gAs UK and Global Emissions (GAUGE) project is a four-year measurement and data analysis programme beginning in January 2013, which involves six UK universities led by Prof Paul Palmer at the University of Edinburgh, and includes national agencies such as the Met Office, in collaboration with DECC and other agencies. GAUGE has been designed to measure directly GHG concentrations over the UK in order to characterise and quantify the variety of sources that determine the UK's contribution to the trend and variability of atmospheric concentrations of GHGs globally. I will lead the airborne measurement package of GAUGE by recording measurements in flights around the UK mainland to measure what comes in and what goes out in the air that passes over the UK. These so-called "boundary conditions" are important in understanding what the relative impacts of emissions within the UK are versus what comes in from further afield. For example, it is currently well known that days of poor London air quality are often exacerbated by polluted Continental air entering the UK. By continuous and direct measurement across the UK, models of atmospheric transport and chemistry can be used to determine not only what the UK emits en masse, but also to disaggregate these emissions between specific areas and industries thus providing the acid test of the current approach.

. . . These hazards are not unrecognised . . .

Once again, it is CH_4 that carries the most uncertainty in the UK's GHG emissions inventory and the GAUGE project will strive to better constrain it. The exploratory hydraulic fracturing ("fracking") licences recently granted to Cuadrilla for shale gas extraction in the North West, warrant close attention. This industry could represent an additional new source of methane through what are known as fugitive emissions, or unintended venting of CH_4 to the atmosphere. The routes of emission are not fully understood or quantified but may include localised emissions at the drill site or diffuse emission through potential geological fractures far away. These hazards are not unrecognised and Cuadrilla has plans to capture any vented methane at drill sites. What is called for is appropriate monitoring as this industry expands. A safety hazards assessment has been reported by DECC in May 2012, yet that assessment did not seek to assess environmental hazards, which would include the climate impacts of fugitive emissions and implications for regional air quality. It is my hope that DECC will commission such an assessment before any larger scale roll-out of fracking and that the academic community is properly engaged in that assessment.

The UK has risen to the challenge of meeting its Kyoto pledge and fostered a world-class academic community and infrastructure fit for the purpose of understanding and monitoring of GHGs both nationally and internationally. Methane remains a significant source of uncertainty and work must be continued to monitor and understand how the concentration of this important gas is changing in the atmosphere both within the UK and globally if we are to provide the best possible forecasts of climate change in the future.