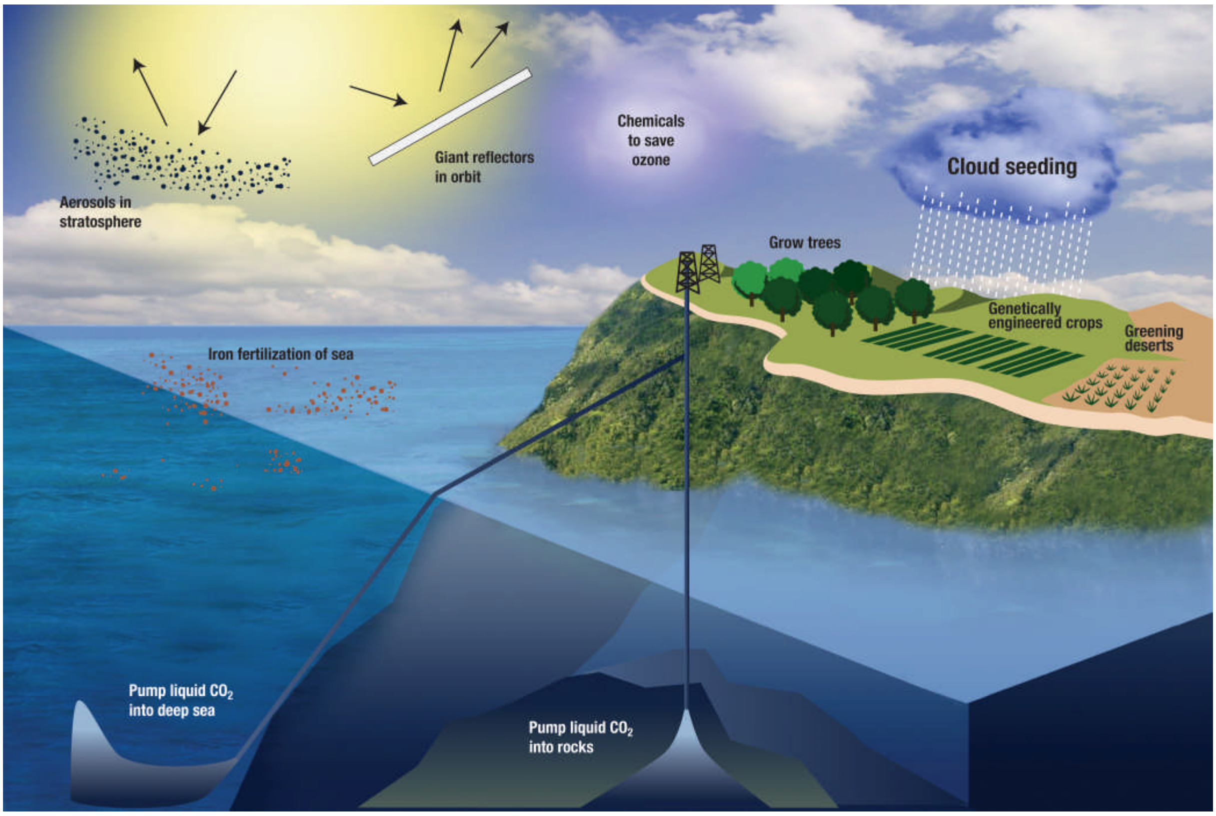
January 2009 1

Royal Society of Chemistry ISSN 1758-6224

Environmental Chemistry Group www.rsc.org/ecg

Bulletin



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Environmental Chemistry Group (ECG) news

Interview—Jo Barnes

2009 ECG Distinguished Guest Lecture: The Future of Water

ECG Atmospheric Chemistry Forum

ECG Contaminated Land Meeting

National Centre for Atmospheric Science (NCAS) Summer School and Conference

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Bulletin

Published biannually by the Royal Society of Chemistry's (RSC) Environmental Chemistry Group (ECG), Burlington House, Piccadilly, London, W1J 0BA, UK

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Environmental Chemistry Group

www.rsc.org/ecg

The Environmental Chemistry Group explores all aspects of the complex relationships between chemistry and the environment, including organising symposia and publishing the *Bulletin*. The ECG works closely with the RSC's Environment, Sustainability and Energy Forum.

This and previous issues of the *Bulletin* are available without charge online at www.rsc.org/ecg. Print issues are distributed to Members of the ECG. For membership details visit www.rsc.org/Membership

Environmental Chemistry Group News

Burlington House, Piccadilly, London

Environmental Chemistry Group meetings in 2009

One of the core aims of the Environmental Chemistry Group is “to understand the behaviour of chemical species in water, soils and atmospheric environments”, and this year the ECG will be organising a meeting in each of these three areas. “**The Future of Water**” is the topic for this year’s ECG DGL and symposium, which will take place on 4th March 2009. Then two new ECG events have been organised for 2009: an **Atmospheric Chemistry Forum** on 2nd April, which is intended for PhD students and early-career researchers. And later in the year, on 23rd September, a meeting has been arranged on “**Contaminated Land: Contaminant Transport and Fate**”, for professionals from industry, academia and local government. All three meetings will be held at the Royal Society of Chemistry’s headquarters, Burlington House, Piccadilly, and full details of these meetings may be found elsewhere in this issue of the ECG *Bulletin* – ECG DGL, p 20; Atmospheric Chemistry Forum, p 25; and Contaminated Land: Contaminant Transport and Fate, p 23.

STEPHEN BALL, BILL BLOSS and JAMES LYMER (ECG Committee Members)

ECG *Bulletin*

This issue of the ECG *Bulletin* features articles on two chemicals which are of particular concern for the environment, and which have been discussed in many previous issues since this publication began in January 1995 (as the *ECG Newsletter*): *arsenic* (in its chemically-speciated forms) and *carbon dioxide*.

Use of groundwater as a source of ‘clean’ drinking water in Bangladesh was followed by the realisation of the serious heath effects caused by the presence of high levels of dissolved *arsenic*. Groundwater from deltaic locations in other countries was also found to be contaminated with arsenic. An explanation of the geological causes of arsenic pollution was published in *Nature* in 1998 and reported in the *ECG Newsletter*, January 1999. Now the group from University College London (UCL), who first suggested some of the geochemical factors responsible for arsenic pollution, has investigated the reasons why there is a variation in the concentrations of arsenic in drinking-wells in Bangladesh, even in wells of close proximity. Based on this new research, **Professor John McArthur** from UCL has written an account of his group’s work especially for this issue of the ECG *Bulletin* (pp 5–8).

Professor McArthur has also written ‘A guide to arsenic pollution of groundwater in Bangladesh and West Bengal’, which appears on

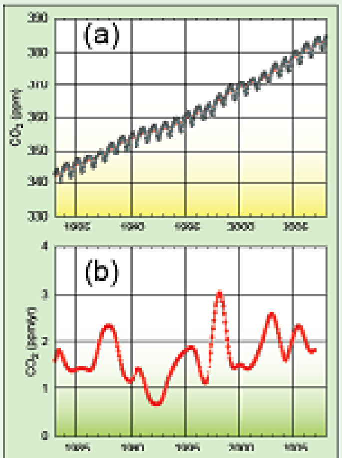

Figure 3. Globally averaged CO_2 (a) and its growth rate (b) from 1983 to 2007.

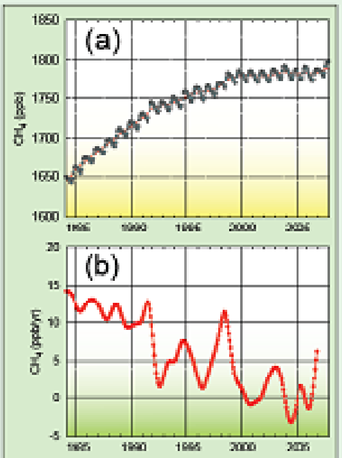

Figure 4. Globally averaged CH_4 (a) and its growth rate (b) from 1984 to 2007.

the web page of the ECG *Bulletin* Archive as a supplementary article to the ECG *Bulletin*, January 2006 www.rsc.org/ecg.

Anthropogenic *carbon dioxide* has long left the confines of academic journals and become the currency of national and international debate. Issues of the ECG *Bulletin* have described the impact of carbon dioxide on the climate; national and international protocols to limit carbon dioxide emissions; and the measurement of atmospheric CO_2.

The latest *WMO Greenhouse Gas Bulletin*, No. 4, November 2008, published by the World Meteorological Office (WMO) highlights the continuing increase in the atmospheric concentrations of carbon dioxide (and methane) up to 2007 [**Figures 3 & 4** from *WMO Greenhouse Gas Bulletin*, No. 4, reproduced by the kind permission of Ed. Dlugokencky (WMO), Geir O. Braathen (WMO), and Kazuto Suda (Japan Meteorological Agency): Web link: http://www.wmo.int/pages/index_en.html].

In 2007, global concentrations of carbon dioxide again reached the highest levels ever recorded. The latest data show that carbon dioxide reached 383.1 parts per million (ppmv), an increase of 0.5 percent from 2006.

Against this background of continuing annual increases in atmospheric CO_2, a recent thematic issue of the *Philosophical Transactions of the Royal Society A* was devoted to large-scale geoengineering works, which have been devised or hypothesised to avert catastrophic climate change caused by anthropogenic carbon dioxide. From that issue, and with the kind permission of the author and of the Royal Society, an extended extract from a paper by **Professor James Lovelock** CH on the consequences posed by increases in atmospheric CO_2 over a relatively short time-scale, and the options available to mitigate global CO_2 levels, is reproduced on pp 9-13 of this edition of the ECG *Bulletin*.

On a smaller engineering scale, carbon-capture technology is being actively pursued as coal re-emerges as an economically viable energy source. The ECG is currently planning its **2010 ECG Distinguished Guest Lecture** on the topic of the environmental impacts of coal power.

Elsewhere in this issue of the ECG *Bulletin*, **Pat Bellamy** from Cranfield University reports on some findings of the National Soil Inventory of England and Wales, and we begin a series of interviews with scientists and others whose work helps us to understand the environment and its chemistry. Finally, a third chemical, water, without which we would not have the environment (or the biota), is the topic (from an economic rather than a scientific perspective) for the **2009 ECG Distinguished Guest Lecture and Symposium**.

RUPERT PURCHASE (Editor, ECG *Bulletin*)

Arsenic pollution in groundwater: another piece of the puzzle falls into place

Whilst the detrimental health effects of arsenic-contaminated drinking water may have receded from the headlines of late, the underlying geological causes of this human tragedy remain. Pioneering work by geologists and geochemists from University College London (UCL) on a mechanism for arsenic pollution in groundwater was reported in the *ECG Newsletter* at the turn of the last decade. Now as the first decade of the new century concludes, another mechanism for arsenic pollution has emerged, as Professor John McArthur from UCL explains.

River sediments and aquifers

River sediments: a source of drinking water. Rivers lay down sediment in floodplains on their way to the sea, and in deltas where they meet the sea. The sediment is often sandy and porous. After burial, such sands may form important underground reservoirs of freshwater (aquifers) that are exploited for domestic supply. Such aquifers are termed 'alluvial' or 'deltaic' because of their riverine origin. Groundwater from alluvial aquifers worldwide provides much of the world's supply of drinking water. That drawn from the alluvial aquifers of Asian deltas—the Ganges/ Brahamaputra, the Mekong, the Red River, the Irrawaddy, and many others—does so for a fifth of the region's population.

Arsenic pollution of groundwater. In the 1970s, it was widely held that alluvial aquifers everywhere yielded wholesome groundwater. That notion led to the promotion, especially in Bangladesh and West Bengal, of the use of groundwater as a safe alternative to microbiologically-polluted surface water for domestic supply. But the groundwater in those countries was soon proven to be hazardous and affected by severe pollution by naturally-occurring dissolved arsenic. The problem was revealed successively in West Bengal, Bangladesh, Vietnam, and Cambodia, and is now known to occur in 30 deltaic and coastal aquifers worldwide (Ravenscroft *et al*., 2009 and references therein). It is clear that the pollution is severe and global in extent.

Levels of dissolved arsenic. By the term pollution is meant concentrations of dissolved arsenic that exceed local water-quality standards of 50 µg/L As, or the World Health Organization's (2006) guideline value of 10 µg/L As. In many alluvial aquifers, arsenic concentrations of several hundred milligrams per litre are common in groundwater. Dissolved arsenic is odourless, tasteless, poisonous, and carcinogenic. Its danger lies in its long period of carcinogenic latency, which is measured in years to decades. As a consequence, in Bangladesh alone, the affect of natural As-pollution of groundwater was termed "the worst mass poisoning of a population in history" by Smith *et al*. (2000), who predicted that, by 2010, one in ten deaths in the area would be arsenic-related unless effective remediation alleviated the problem (*ibid*.).

The distribution of arsenic pollution

A mechanism for arsenic pollution. The natural As-pollution in Bangladesh was soon shown to derive from reductive dissolution of sedimentary iron oxide (FeOOH; Nickson *et al*., 1998 *et seq*.). Sediments contain iron oxides (often abbreviated to FeOOH) derived from mineral weathering and this FeOOH strongly sorbs arsenic. As long as some FeOOH remains in the sediment, arsenic remains sorbed to the FeOOH and arsenic pollution is absent from

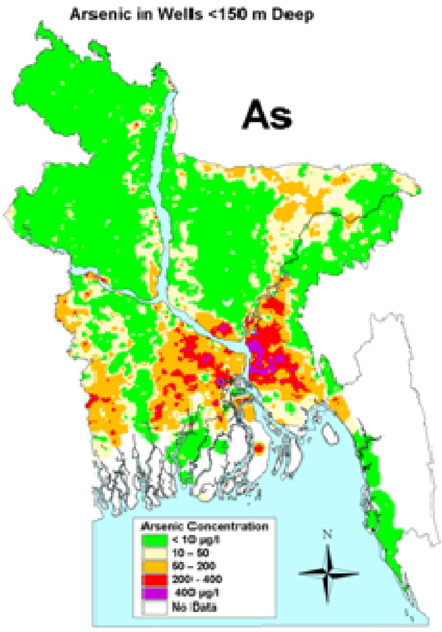

Figure 1: *Distribution of arsenic pollution in Bangladesh. The map shows the average (or most probable) arsenic concentration in the upper 150 m of the alluvial aquifer system.*

groundwater. But in sediments, microbial oxidation of organic matter commonly extracts from FeOOH the oxygen needed for *C*-oxidation, leaving the Fe(II), and its sorbed arsenic, free in solution as waste products. As a consequence, sands that retain FeOOH are not polluted by arsenic because the FeOOH sorbs it and prevents it appearing in solution. Where the FeOOH had been destroyed by reduction, arsenic pollution can be severe.

Distribution of arsenic pollution. Whilst the mechanism of pollution is clear (albeit details continue to emerge), the factors that controls the distribution of the pollution are less clear. It was shown by Peter Ravenscroft, and his team at Mott MacDonald International in Dhaka and the University of Dhaka (DPHE 1999), to be patchy at all scales, from country-wide to village level (**Figure 1**). He also showed that sea-level change strongly influenced the distribution of As-pollution, apparently confining it to sands deposited after a low-stand of sea-level that occurred around 20,000 years ago. That was the time at which glacial ice, and the world's ice-caps reached their maximum extent in the last ice-age, so the time is termed by geologists the Last Glacial Maximum (LGM; ≈20 ka). Ravenscroft showed that deep wells (mostly >150m deep) were arsenic-free because they drew water from old sand deposited before the LGM.

A new model for arsenic pollution. Whilst the work of Ravenscroft's team explained why deep wells were not polluted by arsenic, it did not explain why some 25% of wells drawing water from younger sands were arsenic polluted, and 75% were not. This arsenic pollution is patchy: of two wells within metres of each other, one might be arsenic-free whilst the other is polluted with arsenic. There had to be more to the story. Another piece of the jigsaw has just been put in place by a paper published by the London Arsenic Group (McArthur *et al.*, 2008). The group undertook extensive drilling and shallow geophysical measurements of sediment resistivity in order to understand what it was in the subsurface that gave this patchy distribution of arsenic, and they appear to have discovered the reason. As a result, the paper has set forth a new model of arsenic pollution that may explain the patchy distribution of arsenic in the groundwater of the Bengal Basin and so in deltaic aquifers worldwide where arsenic pollution occurs.

The palaeosol model of arsenic pollution

Palaeosol formation. The model sets As-pollution in the context of sea-level change, weathering, and the formation of ancient soils (termed palaeosols) by continental weathering. Sea-level decreased in level by about 120 m between 125 ka and 20 ka, as the last ice-age developed to its maximum. Falling sea-level exposed the world's coastal areas to subaerial weathering.

In deltas worldwide, this lowering caused rivers to incise into the exposed coastal plains to maintain their base levels as close as possible to sea-level. The exposed regions between the rivers, termed the interfluves (**Figure 2**) were not eroded by rivers but were weathered subaerially and developed a capping of impermeable clay soil, termed a palaeosol (**Figures 2 & 3**). Sands underlying the palaeosol were also weathered by oxygenated groundwater flowing through them. The sands were turned brown in colour as they became FeOOH rich. This weathered, oxidized, and eroded, landscape was buried by later (post LGM) sediments as sea-level rose between 20 ka and 6 ka to near its present level, pushing the sea-shore landward, backing up the rivers, and making them deposit their sediment load so as to build the modern delta we call Bangladesh. In the Bengal Basin, the sediments included organic-rich silts and muds to drive FeOOH-reduction and cause As-pollution in these post-LGM sands.

Palaeosols influence arsenic distribution. The key postulate of the 'palaeosol model' is that the weathering of interfluves between 125 ka and 20 ka capped the oxidised Pleistocene brown sands with an impermeable palaeosol, termed the Last Glacial Maximum Palaeosol (LGMP). The LGMP formed regionally, if discontinuously, and has a major impact on groundwater flow (**Figure 3**), thus controlling the distribution of As-pollution. The LGMP controls flow because it is impermeable.

Potamology, palaeosols and arsenic. The LGMP prevents vertical recharge reaching brown-sand aquifers beneath the palaeo-interfluves (**Figure 3**) and so protects them from both downward percolation of As-polluted water, and also

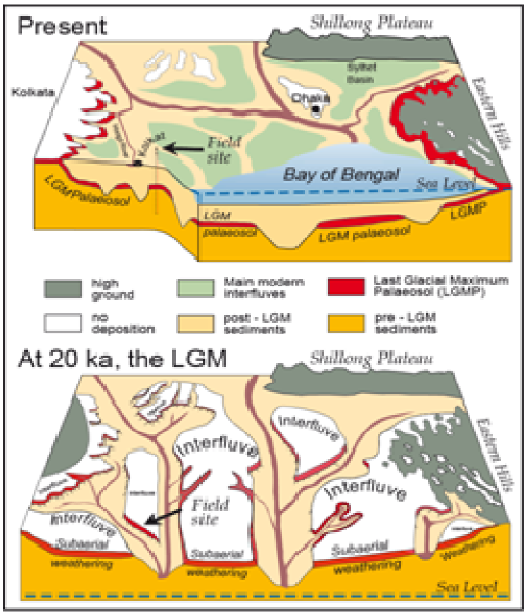

Figure 2: *Schematic of palaeosol development on palaeo-interfluvial areas of the Bengal Basin between 125 ka and the last glacial maximum at 20 ka. The palaeosol is here termed the Last Glacial Maximum Palaeosol, or LGMP. Arrows show the location of the detailed cross section in Figure 3. The size of interfluves is schematic only; their true extent and degree of continuity is unknown.*

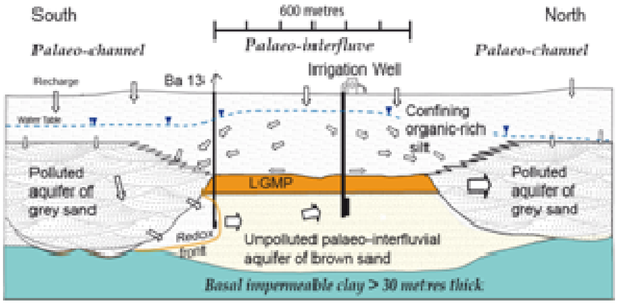

Figure 3: *The LGM palaeosol and its effect on groundwater flow. Section across the field site shown in Figure 2. Open arrows show groundwater flow direction; size denotes flow magnitude. The LGMP prevents vertical recharge to brown sands beneath it, so preserving them as unpolluted aquifers. Horizontal flow moves organic matter (to reduce FeOOH) and arsenic (to pollute) into the brown sand aquifer beneath the LGMP, thereby threatening the palaeo-interfluvial aquifer.*

from downward migration of organic matter (OM), from overlying OM-rich sediments, that would drive reduction of FeOOH and cause As-pollution. A consequence of this prevention of vertical flow is that FeOOH in palaeo-interfluvial aquifers has suffered little reduction, and the sands remain today both brown and FeOOH-rich, so their groundwater is As-free. In contrast, the old river channels, now buried and so termed palaeo-channels, contain no LGMP, either because it was never deposited in active river channels, or because it was removed after formation by post-LGM erosion (**Figures 2 and 3**). Palaeo-channels contain no barrier to downward flow of arsenic or organic matter so both have moved downwards in them to both pollute and reduce FeOOH in underlying sands of all ages.

The LGMP prevents vertical flow, but not horizontal flow, so why do palaeo-interfluvial aquifers of brown sand exist some 6,000 years after basin-filling largely ceased as sea-level reached its present level? Why have the palaeo-interfluves not been invaded laterally by arsenic to pollute, and by organic matter to reduce FeOOH (**Figure 3**) and further pollute? More importantly, if it has not happened by now, will it ever: will such aquifers always be safe from lateral invasion by pollution?

One reason for the survival of palaeo-interfluvial brown sands is that their depth of >20m is below base-level. The elevation of much of the deltaic regions of the world is close to sea-level; in the Bengal Basin, the elevation of the land is typically only 5 to 10 metres above sea-level. Because of this low elevation, water at 20m depth below ground level is below sea-level. At such depth where the topography is flat, as it is in deltas, flow is slow because no hydraulic head exists to drive it. With little flow, palaeo-interfluves suffered little lateral invasion by pollution. What little occurred would, for arsenic, have been retarded by sorption to FeOOH in brown, palaeo-interfluvial sands. Organic matter would have been retarded by reaction with FeOOH, with the arsenic released being re-sorbed immediately downflow (Welch *et al*., 2000).

But since the introduction of pumping of groundwater for irrigation in the 1970s, groundwater flow to even 30 m depth is no longer natural or slow; both velocity and flow-depth have increased; subsurface flow is now strong. In the McArthur *et al*. field area (**Figure 4**), irrigation pumping has reversed the natural southerly flow direction, which is now northwards, from As-polluted palaeo-channels into unpolluted palaeo-interfluves (**Figures 3 & 4**). This modern flow carries pollution into the palaeo-interfluvial aquifers. The invading pollution/redox front threatens the reserves of good-quality groundwater present in palaeo-interfluvial areas. Movement of the front is the reason why wells positioned near it (*e.g.* Ba 2, 13; **Figures 3 and 4**) have changed their As-concentration with time, some increasing as the front approached and some decreasing after it had passed.

To quantify the threat posed by the irrigation-induced migration of arsenic, it will be necessary to determine the rate at which arsenic and organic matter (to cause FeOOH reduction) in the front are moving, and how effective the brown sand of the palaeo-interfluves is at sorbing arsenic. Current estimates are that the front is moving at around 1–5 metres per year, and McArthur and his team have just received funding to undertake further studies to improve

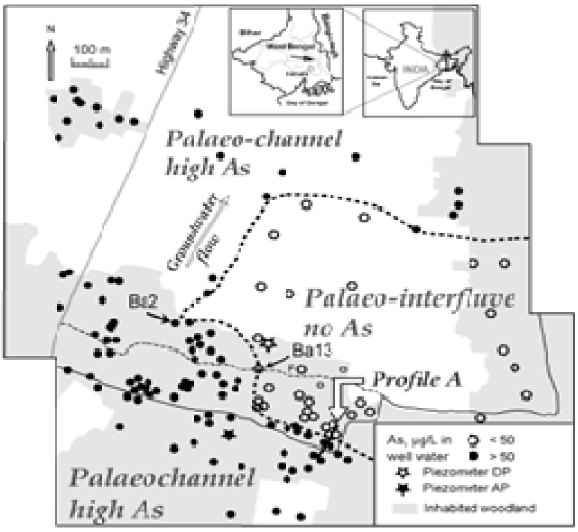

Figure 4: *The study area of McArthur et al (2008), and the distribution of arsenic in the shallow groundwater (<50m depth): flow is to the NNE. A palaeo-interfluve, defined by drilling, well-mapping, and geophysics, is flanked on W, N, and S (E is unknown) by As-polluted palaeochannels. Along the S edge of the interfluve, a redox/As front is moving NNE in response to groundwater flow, and has increased the As-content of Well Ba 13, and decreased it in Well Ba 2, since 2002.*

these estimates. The factors controlling the rate of As-migration must be quantified as they will determine the lifetime of unpolluted palaeo-interfluvial supplies. What is sure is that the reserves of low-As water extractable from palaeo-interfluves will exceed the aquifer volume because invading As-polluted water loses arsenic by sorption to brown sands as it enters the palaeo-interfluves, which act as giant, *in situ*, As-removal filters. A knowledge of the rates of As-pollution will be applicable, within broad limits, to aquifers worldwide, albeit modified by local hydrogeological factors.

The implications of the palaeosol model beyond the Bengal Basin

Because the decline in sea-level from 125 to 20 ka was eustatic and so worldwide, palaeosol formation was also worldwide in deltaic aquifers. It is therefore no surprise that the LGMP has equivalents in other deltas where arsenic pollution is extensive *e.g.* in western India, the Red River Basin of Vietnam, and the Po Valley of Italy (references in McArthur *et al*., 2008). The LGM palaeosol is also widespread in shallow-marine settings that were subaerial during the LGM (*e.g*. Yellow Sea, South China Sea, Sunda Shelf) thus attesting to its widespread occurrence.

If correct, the ‘palaeosol’ model will provide a conceptual framework within which to understand the distribution of pollution, not just pollution by arsenic, in most, if not all, deltaic aquifers, worldwide, as the eustatic lowering of sea-level, and associated weathering of the exposed coastal areas, affected all deltas between 125 ka and 18 ka. The ‘palaeosol model’ also requires a change in the concept of flow in deltaic aquifers away from a view that pollutants (and not just arsenic) migrate vertically downwards over wide areas, towards one where flow is mostly horizontal until intercepted by a local palaeo-channel, at which point it will be concentrated to flow vertically downward in the high permeability palaeo-channel. That understanding will underpin exploration and exploitation of shallow, low-As, sources of water across the Bengal Basin and more widely, and prove useful to all those involved in water-quality monitoring and health surveys.

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London Arsenic Group: www.es.ucl.ac.uk/research/lag/as/

Acknowledgement: Figure 1 was prepared by Peter Ravenscroft using data collected during the “Groundwater Studies for Arsenic Contamination in Bangladesh” project during 1998 and 1999. This project was funded by DFID on behalf of the Bangladesh’s Department of Public Health Engineering (DPHE), and carried out by Mott MacDonald Ltd and the British Geological Survey. Further maps of arsenic distribution in Bangladesh may be seen at www.es.ucl.ac.uk/research/lag/as/pdf/BangladeshArsenicMaps.ppt

A geophysiologist's thoughts on geoengineering

"The Earth is now recognized as a self-regulating system that includes a reactive biosphere; the system maintains a long-term steady-state climate and surface chemical composition favourable for life. We are perturbing the steady state by changing the land surface from mainly forests to farm land and by adding greenhouse gases and aerosol pollutants to the air. We appear to have exceeded the natural capacity to counter our perturbation and consequently the system is changing to a new and as yet unknown but probably adverse state. I suggest here that we regard the Earth as a physiological system and consider amelioration techniques, geoengineering, as comparable to nineteenth century medicine."

James Lovelock, *Phil. Trans. R. Soc. A*, 2008, **366**, 3883-3890

Professor James Lovelock was one of the contributors to a special edition of the *Philosophical Transactions of the Royal Society A* on the theme of 'Geoengineering to avert dangerous climate change', which was published by the Royal Society online on September 1st 2008 and in print on November 13th 2008. With the kind permission of the Royal Society and of the author, we reproduce an extended extract from James Lovelock's article.

Introduction

If geoengineering is defined as purposeful human activity that significantly alters the state of the Earth, we became geoengineers soon after our species started using fire, for cooking, land clearance and smelting bronze and iron. There was nothing unnatural in this; other organisms have been massively changing the

Earth since life began 3.5 Gyr ago. Without oxygen from photosynthesizers, there would be no fires. Morton (2007) in his remarkable book *Eating the Sun* describes the crucial role of these organisms in shaping the evolution of the Earth and its climate.

Organisms change their world locally for purely personal selfish reasons; if the advantage conferred by the 'engineering' is sufficiently favourable, it allows them and their environment to expand until dominant on a planetary scale.

Our use of fires as a biocide to clear land of natural forests and replace them with farmland was our second act of geoengineering; together these acts have led the Earth to evolve to its current state. As a consequence, most of us are now urban and our environment is an artefact of engineering. During this long engineering apprenticeship, we changed the Earth, but until quite recently, like the photosynthesizers, we were unaware that we were doing it, still less the adverse consequences.

It might seem that the fourth assessment report of the IPCC (2007) by over 1000 of the world's most able climate scientists would provide us with most of what we need to know to ameliorate adverse climate change. Unfortunately, it does not; the conclusions so far are tentative and preliminary. The gaps that exist in our knowledge about the state of the oceans, the cryosphere and even the clouds and aerosols of the atmosphere make prediction unreal. The response of the biosphere to climate and compositional change is even less well understood; most of all, we are ignorant about the Earth as a self-regulating system and only just beginning to recognize that many separate but connected subsystems exist that can exert positive and negative feedback on a global scale.

It was not until 2001 that the Amsterdam Declaration stated as follows: *the Earth system is a self-regulating system comprising the atmosphere, oceans and surface rocks and all of the organisms, including humans*. Earth system science is acknowledged, but like a new book that one day we will read, it stays on the shelf. Consequently, the climate models of the IPCC are still based on atmospheric physics and the programs of their models do not yet include the code needed for a self-regulating Earth. Land and ocean surface changes are touched on but mainly from the viewpoint of their passive effect on the atmosphere.

Even Lenton's (2006) review of climate change to the end of the millennium still appears to view the climate as mainly determined by geophysics. This concentration on atmospheric physics is a natural consequence of the evolution of climate science from weather forecasting, but most of all this is because there has been neither the time nor the resources to do more. We may soon need to try geoengineering because careful observation and measurement show that climate is changing faster than forecast by the gloomiest of the IPCC models (Rahmstorf *et al*., 2007).

Geoengineering techniques

Physical means of amelioration, such as changing the planetary albedo, are the subject of other papers of this theme issue and I thought it would be useful here to describe physiological methods for geoengineering. These include:

- tree planting;
- the fertilization of ocean algal ecosystems with iron;
- the production of biofuels; and
- the direct synthesis of food from inorganic raw materials.

I will also briefly describe the idea that oceans be fertilized to encourage algal growth by mixing into the surface waters the nutrient-rich water from below the thermocline using **ocean pipes**.

Tree planting would seem to be a sensible way to remove CO_2 naturally from the air, at least for the time it takes for the tree to reach maturity. But in practice the clearance of forests for farmland and biofuels is now proceeding so rapidly that there is little chance that tree planting could keep pace. Forest clearance has direct climate consequences through water cycling and atmospheric albedo change and is also responsible for much of the CO_2 emissions.

Agriculture in total has climatic effects comparable to those caused by fossil fuel combustion. For this reason, it would seem better to pay the inhabitants of forested regions to preserve their trees than plant new trees on cleared ground. The charity Cool Earth exists to gather funds for this objective. It is insufficiently appreciated that an ecosystem is an evolved entity comprising a huge range of species from micro-organisms, nematodes, invertebrates, small and large plants, animals and trees. While ecosystems have the capacity to evolve with climate change, plantations can only die.

Oceans cover over 70 per cent of the Earth's surface and are uninhabited by humans. In addition, most of the ocean surface waters carry only a sparse population of photosynthetic organisms, mainly because the mineral and other nutrients in the water below the thermocline do not readily mix with the warmer surface layer. Some essential nutrients such as iron are present in suboptimal abundance even where other nutrients are present and this led to the suggestion by John Martin in a lecture in 1991 that **fertilization with the trace nutrient iron** would allow algal blooms to develop that would cool the Earth by removing CO_2 (see Watson 1997).

Lovelock & Rapley (2007) suggested the use of a system of large **ocean pipes** held vertically in the ocean surface to draw up cooler nutrient-rich water from just below the thermocline. The intention was to cool the surface directly, to encourage algal blooms that would serve to pump down CO_2 and also to emit gases such as DMS, volatile amines and isoprene (Nightingale & Liss, 2003), which encourage cloud and aerosol formation. The pipes envisaged would be approximately 100 m in length and 10 m in diameter and held vertically in the surface waters and equipped with a one-way valve. Surface waves of average height 1 m would mix in 4 tons of cooler water per second.

Our intention was to stimulate interest and discussion in physiological techniques that would use the Earth system's energy and nutrient resources to reverse global heating. We do not know whether the proposed scheme would help restore the climate, but the idea of improving surface waters by mixing cooler nutrient-rich water from below has a long history; indeed, it is at present used by the US firm Atmocean Inc. to improve the quality of ocean pastures.

The idea of ocean pipes for geoengineering was strongly resisted by the scientific community on the grounds that their use would release CO_2 from the lower waters to the atmosphere. We were aware of this drawback, but knowing that the low CO_2 levels during the glaciation were reached when the ocean was less stratified than now, we thought that algal growth following the mixing might take down more CO_2 than was released. The next step would be the experimental deployment of the pipes, observations and measurements.

Planting crops specifically for fuel, although sometimes an economic necessity, is a source, not a sink, for CO_2. **Biofuels** might be made green again if sufficient of the waste carbon from the plants could be permanently buried. Thus if any of the ocean fertilization schemes work, their value could be enhanced by harvesting the algae, extracting food and fuel and then burying the waste in the deep ocean as heavier-than-water pellets. This would remove a sizeable proportion of the carbon photosynthesized and place it as an insoluble residue on the ocean floor. The temperature of the deep ocean is close to 4 °C and the residence time of water there is at least 1000 years. The buried carbon would effectively be out of circulation. It might be possible also to bury land-based agricultural waste at these deep ocean sites. This idea may be even more unpopular than the pipes. Critics rightly fear that waste buried in the ocean might be a source of nitrous oxide or other greenhouse gases, but again we may before long reach desperate times; so should we reject an experimental burial of carbon now?

Another amelioration technique is the **direct synthesis of food from CO_2**, nitrogen and trace minerals. When food was abundant, it seemed an otiose proposal, but not now since food prices are rising. Massive crop failure in future adverse climates would give food synthesis an immediately vital role. The procedure for food synthesis would involve the production of a feed stock of sugars and amino acids from air and water as an industrial chemical operation, using either renewable or nuclear energy. This basic nutrient would be fed to tissue cultures of meat or vegetable cells and then harvested as food. Something similar to this kind of synthesized food already exists in a commercial form. It is a cultured mycoprotein product, and supermarkets sell it under the brand name 'Quorn'.

Misplaced fear stops us from using nuclear energy, the most practical and available geoengineering procedure of all; we even ignore the use of high temperature nuclear reactors for the synthesis of food and liquid fuels directly from CO_2 and water.

Geophysiology

The Earth system is dynamically stable but with strong feedbacks. Its behaviour resembles more the physiology of a living organism than that of the equilibrium box models of the last century (Lovelock 1986). Broecker (1991) has shown by observation and models that even the wholly physical models of the Earth system are nonlinear, often because the properties of water set critical points during warming and cooling. These include the heat-driven circulation of the oceans. The phase change from ice to water is accompanied by an albedo change from 0.8 to 0.2 and this strongly affects climate (Budyko, 1969). There are other purely physical feedbacks in the system: the ocean surface stratifies at 12–14 °C, the rate of water evaporation from land surfaces becomes a problem for plants at temperatures above 22–25 °C and atmospheric relative humidity has a large direct effect on the size and effective albedo of aerosols. In a simple energy balance model, Henderson-Sellers & McGuffie (2005) show the large climate discontinuity between the ice free and icy worlds and marked hysteresis.

Model systems that include, in addition to geophysics, an active and evolving biota self-regulate at physiologically favourable temperatures. Lovelock & Kump (1994) described a zero-dimensional model of a planet that self-regulated its climate; it had land surfaces occupied by plants and the ocean was a habitat for algae. This model system was normally in negative feedback with respect to temperature or CO_2 increase, but when subjected to a progressive increase of CO_2 or heat flux, regulation continued at first, but as the critical CO_2 abundance of 450 ppm, or heat input of 1450W m-2, was approached, the sign of the feedback changed to positive and the system began to amplify and did not resist change. At the critical point, amplification rose steeply and precipitated a 6 °C rise in temperature. Afterwards the system returned to negative feedback and continued to self-regulate at the higher temperature. As with the ice albedo feedback, there was marked hysteresis and reducing CO_2 abundance or heat flux did not immediately restore the state prior to the discontinuity.

The justifications for using this tiny zero-dimensional model to argue against the powerful forecasts of the giant global climate models are these. First, it is a model in which the biota and the geosphere play an active dynamic role, as in the model daisyworld (Watson & Lovelock, 1983) from which it has descended. Second, it makes predictions that are more in accord with the Earth's history. It suggests that attempts at amelioration should take place before the critical point is reached. Unfortunately, when the large effect of unintentional cooling by short-lived pollution aerosols is taken into account, we may already be past this point and it would be unwise to assume that climate change can simply be reversed by reducing emissions or by geoengineering.

An engineer or physiologist looking at the IPCC forecasts for this century would find unconvincing their smooth and uninterrupted temperature rise until 2100, something expected of the equilibrium behaviour of a dead planet such as Mars. A glance at the Earth's recent history reveals a climate and atmospheric composition that fluctuates suddenly as would be expected of a dynamic system with positive feedback. The long-term history of the Earth suggests the existence of hot and cold stable states that geologists refer to as the greenhouses and the ice houses. In between are metastable periods such as the present interglacial.

The best known hot house happened 55 Myr ago at the beginning of the Eocene period (Tripati & Elderfield, 2005; Higgins & Schrag, 2006). In that event, between one and two terratons of carbon dioxide were released into the air by a geological accident. Putting this much CO_2 in the air caused the temperature of the temperate and Arctic regions to rise by 8 °C and of the tropics by 5 °C and it took *ca*. 200 000 years for conditions to return to their previous states. Soon we will have injected a comparable quantity of CO_2

and the Earth itself may release as much again when the ecosystems of the land and ocean are adversely affected by heat.

The rise in CO_2 55 Myr ago is thought to have occurred more slowly than now; the injection of gaseous carbon compounds into the atmosphere might have taken place over a period of ca 10 000 years, instead of ca. 200 years as we are now doing. The great rapidity with which we add carbon gases to the air could be as damaging as is the quantity. The rapidity of the pollution gives the Earth system little time to adjust and this is particularly important for the ocean ecosystems; the rapid accumulation of CO_2 in the surface water is making them too acidic for shell-forming organisms (The Royal Society, 2005). This did not appear to happen during the Eocene event, perhaps because there was time for the more alkaline deep waters to mix in and neutralize the surface ocean.

Despite the large difference in the injection times of CO_2, the change in the temperature of approximately 5 °C globally may have occurred as rapidly 55 Myr ago as it may soon do now. The time it takes to move between the two system states is likely to be set by the properties of the system more than by the rate of addition of radiant heat or CO_2. There are differences between the Earth 55 Myr ago and now. The Sun was 0.5 per cent cooler and there was no agriculture anywhere so that natural vegetation was free to regulate the climate. Another difference was that the world was not then experiencing global dimming—the 2–3 °C of global cooling caused by the atmospheric aerosol of man-made pollution (Ramanathan et al., 2007). This haze covers much of the Northern Hemisphere and offsets global heating by reflecting sunlight and more importantly by nucleating clouds that reflect even more sunlight. The aerosol particles of the haze persist in the air for only a few weeks, whereas carbon dioxide persists for between 50 and 100 years. Any economic downturn that reduced fossil fuel use would reduce the aerosol density and intensify the heating and so would the rapid implementation of the Bali recommendation for cutting back fossil fuel use.

It is sometimes assumed that the temperature of the sunlit surface of a planet is directly related to the albedo of the illuminated area. This assumption is not true for forested areas. The physiological temperature regulation of a tree normally keeps leaf temperature below ambient air temperature by evapotranspiration, the active process by which ground water is pumped to the leaves; the trees absorb the solar radiation but disperse the heat insensibly as the latent heat of water vapour. I have observed in the southern English summer that dark conifer tree leaves maintain a surface temperature more than 20 °C cooler than an inert surface of the same colour.

Planetary medicine

What are the planetary health risks of geoengineering intervention? Nothing we do is likely to sterilize the Earth, but the consequences of planetary scale intervention could hugely affect humans. Putative geoengineers are in a position similar to that of physicians before the 1940s. The author physician Lewis Thomas (1983) remarkably described in his book, The Youngest Science, the practice of medicine before the Second World War. There were only five effective medicines available: morphine for pain, quinine for malaria, insulin for diabetes, digitalis for heart disease and aspirin for inflammation and very little was known of their mode of action. For almost all other ailments, there was nothing available but nostrums and comforting words. At that time, despite a well-founded science of physiology, we were still ignorant about the human body or the host–parasite relationship it had with other organisms. Wise physicians knew that letting nature take its course without intervention would often allow natural self-regulation to make the cure. They were not averse to claiming credit for their skill when this happened. I think the same may be true about planetary medicine; our ignorance of the Earth system is overwhelming and intensified by the tendency to favour model simulations over experiments, observation and measurement.

Ethics

Global heating would not have happened but for the rapid expansion in numbers and wealth of humanity. Had we heeded Malthus's warning and kept the human population to less than one billion, we would not now be facing a torrid future. Whether or not we go for Bali or use geoengineering, the planet is likely, massively and cruelly, to cull us, in the same merciless way that we have eliminated so many species by changing their environment into one where survival is difficult.

Before we start geoengineering we have to raise the following question: are we sufficiently talented to take on what might become the onerous permanent task of keeping the Earth in homeostasis? Consider what might happen if we start by using a stratospheric aerosol to ameliorate global heating; even if it succeeds, it would not be long before we face the additional problem of ocean acidification. This would need another medicine, and so on. We could find ourselves enslaved in a Kafka-like world from which there is no escape. Rees (2003) in his book *The Final Century*, envisaged a similar but more technologically based fate brought on by our unbridled creativity.

The alternative is the acceptance of a massive natural cull of humanity and a return to an Earth that freely regulates itself but in the hot state. Garrett Hardin (1968) foresaw consequences of this kind in his seminal essay 'The tragedy of the commons'.

Whatever we do is likely to lead to death on a scale that makes all previous wars, famines and disasters small. To continue business as usual will probably kill most of us during the century. Is there any reason to believe that fully implementing Bali, with sustainable development and the full use of renewable energy, would kill less? We have to consider seriously that, as with nineteenth century medicine, the best option is often kind words and pain killers but otherwise do nothing and let Nature take its course.

The usual response to such bitter realism is: then there is no hope for us, and we can do nothing to avoid our plight. This is far from true. We can adapt to climate change and this will allow us to make the best use of the refuge areas of the world that escape the worst heat and drought. We have to marshal our resources soon and if a safe form of geoengineering buys us a little time then we must use it. Parts of the world such as oceanic islands, the Arctic basin and oases on the continents will still be habitable in a hot world. We need to regard them as lifeboats and see that there are sufficient sources of food and energy to sustain us as a species. Physicians have the Hippocratic Oath; perhaps we need something similar for our practice of planetary medicine.

During the global heating of the early Eocene, there appears to have been no great extinction of species and this may have been because life had time to migrate to the cooler regions near the Arctic and Antarctic and remain there until the planet cooled again. This may happen again and humans, animals and plants are already migrating. Scandinavia and the oceanic parts of northern Europe such as the British Isles may be spared the worst of heat and drought that global heating brings. This puts a special responsibility upon us to stay civilized and give refuge to the unimaginably large influx of climate refugees.

Perhaps the saddest thing is that if we fail and humans become extinct, the Earth system, Gaia, will lose as much as or more than we do. In human civilization, the planet has a precious resource. We are not merely a disease; we are, through our intelligence and communication, the planetary equivalent of a nervous system. We should be the heart and mind of the Earth not its malady.

Perhaps the greatest value of the Gaia concept lies in its metaphor of a living Earth, which reminds us that we are part of it and that our contract with Gaia is not about human rights alone, but includes human obligations.

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Past and future uses for the National Soil Inventory of England and Wales

Many samples of soil have been collected over the past fifty years so that soils may be classified and soil maps drawn. The first systematic sampling of soil in England and Wales took place between 1978 and 1980. This soil inventory formed the basis of a soil monitoring network, and there was further resampling between 1995 and 2005. **Mrs Pat Bellamy**, a statistician at the Natural Resources Department, Cranfield University, describes how this unique dataset has revealed large losses of soil carbon across England and Wales, and highlights future applications of the data for the improvement of soil monitoring networks.

Sampling of soil across England and Wales

A National Soil Inventory (NSI) was conducted for England and Wales to obtain an estimate of the distribution of the soils of England and Wales and to study the chemistry of the topsoil. The whole of England and Wales was sampled at each intersection of 5 km x 5 km grids over the interval 1978 to 1983, (Loveland, 1990). Soil profiles were described and topsoil samples taken to a depth of 15cm. Each sample consisted of 25 soil cores taken on a 5 m x 5 m grid in a 20 m x 20 m plot centred on the site. The soil cores were all placed in one plastic bag and returned to the laboratory for analysis. Each sample was analysed for organic carbon, pH, metal concentrations (total and extractable Cd, Co, Cu, Mn, Ni, Pb, Zn and total Al, As, Ba, Ca, Cr, F, Fe, Hg, Mo, Na, Se, Sr, V) and nutrients (P, K, Mg). Site properties such as land use, slope and aspect were recorded.

The South Downs near Pyecombe, West Sussex. Reproduced with permission of Roger Ockenden (*Also p.16*)

A proportion of those sites under arable or rotational grass were resampled in 1995. Some of the permanent grassland sites were resampled in 1996, and the non-agricultural sites were resampled in 2003. Overall 40% of the original 5662 sites were resampled. The protocols which were followed for resampling were those used in the original sampling schedule. Samples and data were all archived for future use and may be seen at LandIS, the Land Information System http://www.landis.org.uk.

Changes in soil carbon

Data from the original National Soil Inventory were used to investigate the change in soil carbon over the sampling interval of 12-25 years. The results showed that carbon was lost from soils across England and Wales over the survey

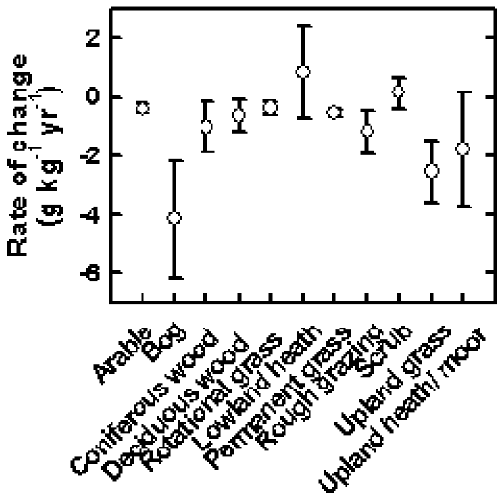

Figure 1: *Annual change in carbon – grouped by land use. Data from Bellamy et al., 2005*

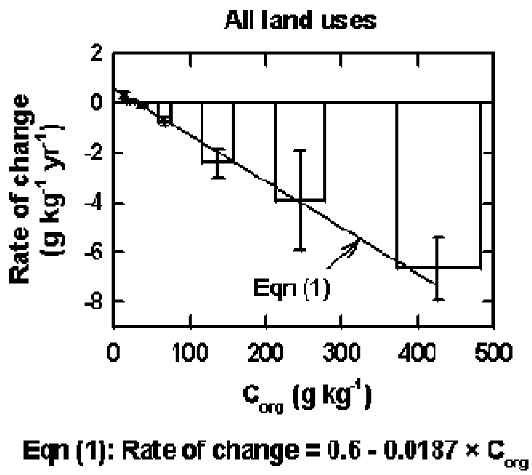

Figure 2*: Annual change in carbon over all land uses. Data from Bellamy et al., 2005*

period at a mean rate of 0.6% yr^{-1}, relative to the existing soil carbon content, (Bellamy *et al*., 2005). **Figure 1** shows the results for each land use recorded. It can be seen that only lowland heath and scrub showed an increase, and this was not a significant increase.

It was found that the relative rate of carbon loss increased with soil carbon content and was more than 2% yr^{-1} in soils with carbon contents greater than 100 g kg^{-1} (**Figure 2**). The equation in **Figure 2** was fitted, using REML with spatial residuals, to the individual data points and was used to estimate the rate of change in soil carbon at those sites which were not resampled.

Using the estimated annual change in carbon content across the whole of England and Wales, an estimate of the carbon stock for these two countries was made using estimates of bulk density (Howard *et al*., 1995). It was estimated that the soils of England and Wales are losing about 4.4 Tg yr^{-1} of carbon. If we assumed that the soils in Scotland and Northern Ireland are similarly losing carbon we estimated the loss of carbon from the whole of the UK was about 13 Tg yr^{-1}. For comparison, the UK's current industrial CO_2 emission is about 150 Tg yr^{-1}

Potential causes of soil carbon losses

Soil carbon contents depend on rates of addition from plant growth versus rates of removal in decomposition, leaching and other soil processes, and each of these is sensitive to changes in land use, climate and other variables, (Guo *et al*., 2002). Various changes in land use will have contributed to carbon losses from soils across England and Wales over the survey period, both from changing agricultural uses (drainage schemes, post-war grassland conversion, increased stocking rates) and non-agricultural uses (afforestation on wet soils, increased erosion, increased burning of upland vegetation).

Over the survey period, the mean temperature across England and Wales increased by about 0.5 ºC and there were also changes in rainfall distribution (Hulme, 2002). Climate change will affect soil carbon turnover through various processes. Increases in temperature will tend to increase rates of organic matter decomposition by soil microbes, although the magnitude of this effect and differences between soils are uncertain (Powlson, 2005). Data on pH from the NSI samples have shown that soils have become more alkaline over the survey period which will also have an effect on the decomposition rate of carbon.

Current research to investigate the causes of soil carbon loss

Data on land use change or management at the NSI sites are very limited. So it is difficult to assess the effect of these influences on the changes in measured soil carbon. However, data on climate across England and Wales are available for the time between the two sampling periods. Work is currently being carried out (under an NERC project) to try to understand the reasons for this large loss soil carbon using models of soil carbon turnover validated using the NSI data.

Also, as the UK is committed under the United Nations Framework Convention on Climate Change and the EU Monitoring Mechanism to produce national inventories of emissions by sources and removals by sinks of greenhouse gases, methane, nitrous oxide, Defra are funding a project to deliver the data for annual inventories and projections into the future for Land Use, Land Use Changes and Forestry (LULUCF). As part of this project we are investigating the possibility of obtaining land use and management information from other sources to investigate the causes of changes in soil carbon at the NSI sites.

Other research carried out using the NSI data

Data from the NSI for the Humber-Trent region in North East England were used to investigate the use of multivariate geostatistics for the problem of estimating temporal change in soil properties for soil monitoring, (Lark *et al*., 2006). The NSI data were combined with GBASE data (British Geological Survey, 2006) for the concentrations of cobalt, nickel and vanadium in the topsoil on two dates. While the concentration of each metal in the soil showed pronounced spatial dependence which is known to be driven by parent material, the change over time was only spatially structured for cobalt and vanadium. This showed that information on spatial variability from a single date may be a poor guide to the design of a monitoring scheme. It was also shown how the cokriging variance of the change in concentration of cobalt and vanadium depended on sampling effort and strategy. [‘Kriging’ and ‘cokriging’ are statistical tools named in honour of the geostatistician Professor D. G. Krige].

The change in these particular variables between two dates is best estimated by sampling with equal intensity at the same sites on both dates; and when resampling an existing baseline survey it is best to sample them at rather than between the original sites. This research is now supporting the design of a UK wide soil monitoring network.

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FOOTNOTE: The National Soil Inventory of England and Wales (NSI) was originally funded by MAFF (now Defra) and carried out by soil surveyors from the Soil Survey of England and Wales, which had offices across England and Wales. The Soil Survey is now named the National Soil Resources Institute and is part of Cranfield University within the Natural Resources Department. The soil samples from the original sampling were analysed in the soil laboratory at Rothamsted Research (where the Soil Survey was based). Soils from the second sampling were analysed in the soil laboratory at the Silsoe campus of Cranfield University which was the home of the Soil Survey from 1989 – 2006. The second sampling was organised by Cranfield University and funded by Defra. The actual sampling was carried out by post-graduate students employed specifically for that task. The analytical methods and techniques for the soil samples are described by Bellamy *et al.* (2005). For the majority of soil samples, organic carbon was measured using the Walkley-Black method.

Cranfield University holds the archive of all the soil samples taken over the two sampling campaigns, and we hope to persuade Defra to fund another sampling for the NSI in the near future.

(*Photo as p.14.*)

The ECG interview: accountancy 0 – environmental science 1!

In the first of a series of interviews for the ECG Bulletin, **Jo Barnes** talks to ECG *Bulletin* Associate Editor **Adrian Kybett** about her role as an air quality environmental scientist in south-west England.

Joanna (Jo) Barnes is a Research Associate in the Air Quality Management Resource Centre, at the University of the West of England and is the RSC's Environmental Chemistry Group's Honorary Secretary – http://www.uwe.ac.uk/aqm/jo.html

What inspired you to become an environmental scientist?

A previous career training to become an accountant! I got so fed up of number fudging and paper pushing and longed to do something more rewarding and meaningful. So in 2000, I went back to college and studied an Access to HE course in Environmental Science and suddenly it all made sense. I love the way it brings together all of the sciences to help us understand our natural environment and particularly our accountability to it!

How did you come to specialise in air quality?

Pure chance and sheer luck. Following the Access course I went on to complete a BSc in Environmental Resource Management at Cornwall College. It was from here, in 2004, that I was given the opportunity to join the Cornwall Air Quality Forum, a collaboration of local authority Environmental Health Officers and transport planners with technical support and academic guidance from Barbara Parsons and Leo Salter in the College research department. At Cornwall College I was given an 'in-at-the-deep-end' education in local air quality management, a relatively new 'science' with local authorities gaining responsibility for assessing and managing emissions in their districts with the implementation of Part IV of the Environment Act 1995.

What kind of things did you work on at Cornwall College and now in your new role as Research Associate at the Air Quality Management Resource Centre, UWE?

In the Air Quality Unit at Cornwall College my main role was in designing and running air quality monitoring programmes on behalf of the local authorities in the CAQF, so dealing with data and equipment, writing reports, GIS mapping, and disseminating results at meetings and conferences. I also managed a couple of EU research projects: investigating ambient concentrations of airborne arsenic in west Cornwall on behalf of the Environment Agency, and monitoring traffic emissions in Cornish towns. In the AQMRC my role has developed somewhat: I now deal with all UK local authorities as well as central government and devolved administrations (DAs), assisting with the Review and Assessment Helpdesk phone line, email and website and appraising and writing local air quality management reports to Defra and the DAs. Although the work at UWE is a lot more desk-based it is just as varied with plenty of opportunities and scope for growth.

What advice would you give to young people considering a career or qualification in environmental science?

Go for it! But be aware that opportunities in ecology and conservation are oversubscribed and poorly paid. You probably won't be the next David Attenborough (unless you're really lucky!) but you might well find your own little niche, whether in a lab or behind a computer desk. Take every opportunity; getting a job in environmental science is all about experience, and a foot in the door straight out of university is invaluable. Get a specialism; do a Masters or a PhD to get yourself a cut above the competition, but make sure the topic is relevant and something you can get excited about. Keep focused – don't lose sight of your goals – environmental science is a broad spectrum and it can open up a range of options, but remember it's harder to get back into a specialist career than it is to drift away from it!

What are some challenges facing the environmental science community at the moment?

One of the most frustrating challenges is a lack of political will in dealing with climate change. There is a real need for leadership from central government, both for local government and the public, to set examples of good practice in environmental stewardship. For all the media interest in the economic 'crisis' there appears to have been little connection made between the co-benefits for the environment and the individuals' pockets that a change in human behaviour, e.g. reducing reliance on fossil fuels, would make. It is frustrating to see what has been described as the "greatest challenge to mankind" take a backseat in favour of more short-term tribulations. What is needed is more of an over-arching 'grand plan' in which the environment is the driving force rather than an 'integration', starting with a complete overhaul of the current system of funding public transport.

What is the most rewarding or interesting aspect of your career so far?

The opportunity to travel (this might seem a little hypocritical given my little rant above!). The chance to present research at national and international conferences has been one of the greatest highlights of my career, and one of the most flattering was being invited to speak on resuspended arsenic at the RSC's AAMG meeting in London last December.

Tell us about your role with the RSC's Environmental Chemistry Group…

I have acted as Honorary Secretary for the Environmental Chemistry Committee since being co-opted in 2005 when I took over from Dr Leo Salter. My main roles for the Committee involve organising the bi-monthly Committee meetings and the AGM, assisting with the organisation of the other meetings run by the ECG and acting as the liaison between the RSC and the Group. I recently attended the Annual Meeting of Interest Groups on behalf of the Committee and RSC Awards Evening. I enjoy being a part of the ECG Committee for the sense of responsibility and the opportunity to meet many interesting people in the field.

If you weren't a scientist what would you do?

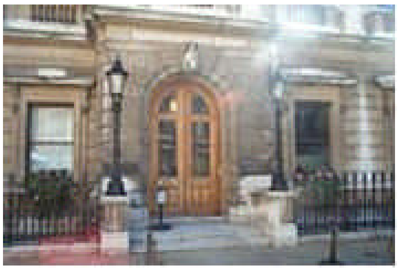
Even if I wasn't working in air quality research I'm sure I would be working in another environmental science-related role. Ideally I'd like a job that allowed me to travel and make a difference, if that doesn't sound too 'Miss World'-y!

& What do you do when you aren't working?

I like to swim, sail and cycle to keep fit, but I also enjoy countryside walks, get-togethers with family and friends, reading, films, music, travel and shopping!

Forthcoming Symposium

The future of water



Burlington House, London

RSC Environmental Chemistry Group—2009 Distinguished Guest Lecture & Symposium

A one-day meeting to be held in the Council Room of the Royal Society of Chemistry, Burlington House, Piccadilly, London on Wednesday, 4th March 2009, from 10:30 am onwards.

The 2009 ECG Distinguished Guest Lecturer will be **Professor Tony Allan** (King's College London)

PROGRAMME

10:30 Coffee/tea and registration

11.00 Chairman's Introduction: Dr Brendan Keely (University of York: Chairman, ECG)

11.05 Dr John W. Sawkins (Heriot-Watt University): *Economic perspectives on water access and affordability*

11.45 Professor Richard C. Carter (Cranfield University): *Navigating water futures in sub-Saharan Africa*

12.30 **Environmental Chemistry Group 36th Annual General Meeting and lunch**

13.15 Lars Steffensen (Ebullio Capital Management): H_2O *'Cost, Insurance and Freight Shanghai' – the next big thing…?*

14.00 Dr P. B. Anand (University of Bradford): *From 'scarcity' to capabilities: connecting economics and human rights in the context of access to water*

14.45 Coffee/tea

15.00 Introduction to the 2009 ECG Distinguished Guest Lecture and presentation of the ECG DGL Medal

15.05 **RSC Environmental Chemistry Group Distinguished Guest Lecture for 2009**: Professor Tony Allan, (King's College London): *The future of water: three weddings and avoiding two funerals*?

16.05 Open Forum

16.30 Close

Coffee/tea will be served at 10.30 and 14.45. A buffet lunch will be served at 12.45

The nearest Tube stations are Green Park and Piccadilly Circus

Admission is by ticket only. In order to register for this meeting, please complete the slip on p. 24 and return to Dr Leo Salter by post, email or fax (see details below). There is a charge of £25 for members of the ECG and £50 for non-members of the ECG (£25 concessions). Cheques should be returned with the slip (made payable to RSC Environmental Chemistry Group). Early application is encouraged as places are limited and will be allocated on a first come first served basis. Five places are reserved free for retired members; these will also be allocated on a first come first served basis.

Contact: Dr Leo Salter, Opie, Cornwall College, Pool, Redruth, Cornwall TR15 3RD leo.salter@cornwall.ac.uk Fax 01209 616230

Abstracts and biographical details of the speakers

Economic perspectives on water access and affordability

Dr John Sawkins, Heriot-Watt University

The issue of access to water will be explored from an economic point of view. The idea of water as both a public (social) and private good will be presented as a prelude to discussing recent public policy initiatives relating to water affordability in selected OECD countries. A brief survey and critique of these policy initiatives is followed by a discussion of possible alternative socio-economic responses to increasing water scarcity that aim to enhance access to water for economically vulnerable consumers in the future.

John Sawkins has held University teaching positions at the Universities of Edinburgh and Aberdeen, and is currently Reader in Economics and Dean (Arts, Humanities and Social Sciences) at Heriot-Watt University, Edinburgh. With a focus on regulatory issues, he has published widely in the area of water economics, acting as a consultant and adviser to government and private sector organisations, and giving oral evidence to Scottish Parliamentary Committees. Since 2003 he has been a member of the consumer representative body, Waterwatch Scotland, and from 2008 will join the board of the Scottish Consumer Council (Consumer Focus Scotland).

Navigating water futures in sub-Saharan Africa

Professor Richard Carter, Cranfield University

The future of water resources in sub-Saharan Africa is dominated by five main sets of inter-related issues:

- population growth and demographic change;
- land use and land cover change;
- climate variability and change;
- poverty, at all levels from household to nation state; and
- a strong dependence on rainfed agriculture.

Some aspects of future water resource trends are known and understood with a high degree of certainty and others with less confidence. But future outcomes under a "business-as-usual" scenario are both predictable and largely negative in terms of water security, food security and public health. If the sub-continent is to avoid the dire consequences which are inevitable under "business-as-usual", two broad possible directions are possible: either "big solutions", with a focus on national economic growth; or grass-roots solutions, with a focus on local social and economic benefits. I will argue that both are needed, but that the necessary strategies to avoid disaster are both complex and inter-sectoral. I will also argue that strenuous efforts need to be made to turn away from present attitudes of dependency, and to focus on approaches which emphasise sustainability above short-term results.

Richard Carter has worked for more than 30 years on the natural science, social science and engineering of water development and management, focusing especially on the poorest countries of sub-Saharan Africa. He undertook his undergraduate, Masters and PhD studies respectively at Cambridge, Southampton and Cranfield Universities. After training as a geologist, he took a Masters degree in irrigation and water resources engineering, and later completed a PhD in water policy and management related to semi-arid west Africa. Richard is driven by a passion to contribute to poverty alleviation in low-income countries and communities. He pursues this goal through long-term partnerships with public sector, private sector and non-Governmental organisations in developing countries. He joined Cranfield University at Silsoe in 1981 after several years working for consulting companies in UK and overseas. He was appointed Professor of International Water Development at Cranfield University in 2002. Richard has worked in Algeria, Bangladesh, Burkina Faso, Canada, Eritrea, Ethiopia, France, Honduras, India, Italy, Ivory Coast, Japan, Malawi, Mali, Malaysia, Netherlands, Nigeria, Pakistan, Rwanda, Sierra Leone, South Africa, Sri Lanka, Swaziland, Switzerland, Tanzania, Uganda, Zaire and Zimbabwe. He has published about 100 papers, articles and reports relating to his work. In 2006 he established Richard Carter & Associates Ltd, to extend and deepen partnerships for rural development in low-income developing countries.

H_2O *'Cost, Insurance and Freight Shanghai' – the next big thing…?*

Lars Steffensen, Ebullio Capital Management LLP

The possible shape that a futures market in water could take will be described. How will the contract look? Where will the delivery points be? Who will trade it? Who will benefit? What are the political ramifications of a futures market on water? And how will a trade in water integrate with the world financial system?

Lars Steffensen is the Managing Partner of Ebullio Capital Management LLP and Managing Director of the Commodity Trading Group and as such is in charge of the team managing The Commodity Fund. Lars Steffensen has 22 years of experience in the commodity industry joining Entores (Metals Brokers) Ltd., London in 1986 and has since then worked for various household names in the metals and commodity industry (Gerald Metals, Philipp & Lion, Axel Johnson Resources, Copenhagen Ore & Metals) in London, Hong Kong, Lugano, Copenhagen, New York and Newport Beach. Along the way, Lars has found the time to be educated in Law and Theology at the University of Aarhus, Denmark. Lars joined Next Energy Inc. in Newport Beach, CA in 1997 and there continued to build on his remarkable track record of impressive returns in commodity trading and rose to Senior Partner in charge of commodity trading. Lars has contributed numerous articles to trade journals such as *The Hedge Fund Journal*, *The Technical Analyst* and others, and has been a speaker at many events and conferences in the commodity hedge fund space. Lars has held an NFA series 3 and 30 license & SFA registration, enjoys sailing, surfing and military & church history and joined the Ebullio Capital Management team in 2007.

From 'scarcity' to capabilities: connecting economics and human rights in the context of access to water

Dr P.B. Anand, University of Bradford

On a blue planet, water scarcity may seem like an oxymoron. However, the so called water scarcity appears to be a reality for many among the 884 million people without access to improved sources of water. What policies are designed and implemented may depend significantly on how societies define and construct scarcity. Viewing scarcity to be a result of too many people or too few water resources can lead us to focus on water as a commodity and pursue a 'paradigm of masculinity' with much emphasis on 'hard' infrastructure investments rather than 'soft' institutions. Amartya Sen's capability approach suggests that we should perhaps turn the question upside down and instead of seeing access to water in terms of how much water individuals have, we should be focusing on the substantive freedoms – valuable beings and doings that access to water allows individuals to achieve. Some studies appear to interpret a capability approach to mean a human right to water. However, it appears that a human right to water can at best be just one side of the story, a rather imperfect one at that. Some countries such as China, India, Tanzania and Namibia appear to have made significant progress in providing access to water without proclaiming a human right to water and others that have promulgated a human right to water have made much less progress. Within a capability approach, an explanation is possible for this paradoxical result. I will aim to discuss this and also explore some potential challenges for implementing a capability approach to water policy.

P. B. Anand is a Reader in Environmental Economics and Public Policy at the University of Bradford. His current research focuses on agency, accountability and governance. His recent research studies focused on design issues related to providing global public goods; on resolution of river water disputes; and on assessing and forecasting progress with regard to water and sanitation targets of the Millennium Development Goals for a research project of the UNU/WIDER. His papers have been published in the *Journal of Human Development*, *Journal of Environment and Development*, *Journal of International Development*, *World Economy*, the *Journal of Development Studies*, *Environment and Urbanisation* and the *Journal of Economic Studies*. His book titled *Scarcity, Entitlements and the Economics of Water in Developing Countries* was published by Edward Elgar in 2007. In this book and several recent papers, Anand has been exploring the application of Amartya Sen's capability approach to water policy and governance issues. Anand's professional profile includes experience of project appraisal, preparing environmental management strategies using stakeholder consultation processes, co-ordinating and leading research studies involving senior professionals, delivering executive education programmes on project planning, public policy analysis, and management to senior and middle level public managers. He has been the team leader of five missions to Ethiopia (2002-03) and a team member of missions to the Caribbean (2007-2009), Tajikistan (2004-2008), Oman (2001), and Nigeria (2005). He has been a convenor of the Environmental Resources and Sustainable Development study group of the Development Studies Association.

The future of water: three weddings and avoiding two funerals?

Professor Tony Allan,
King's College London: the 2009 ECG Distinguished Guest Lecturer

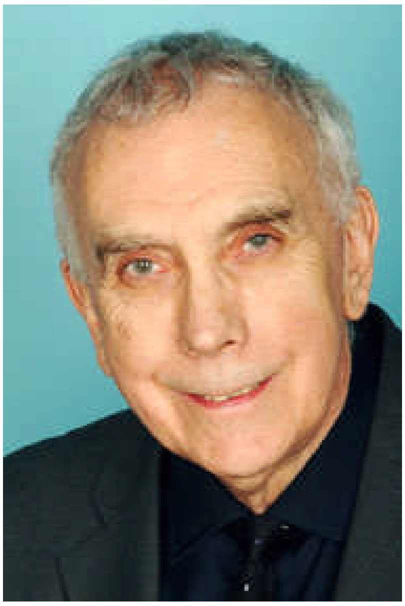
The purpose of the lecture will be to highlight a range of invisible – natural and economic – processes that have not been taken into account by consumers and scientists. Nor by those who allocate and manage water resources. The role of soil water in agriculture has been ignored. The role of trade in ameliorating water scarcity is economically invisible and politically silent. As water is a strategic resource, it is easily politicised. At the same time, in circumstances where the outcomes of mismanaging water are misleading, it is easy for knowledge to be constructed that deludes water consumers. Water scarce societies have not been helped to be wise in their allocation and use of water. The nature and consequences of the invisible processes will be highlighted.

The notion of three weddings and avoiding two funerals will be introduced to capture the future synergies of water and energy and the protection of water and atmospheric services. Three weddings – energy from water, water from energy, and economic diversification plus trade. Avoiding two funerals – requires us to protect the environmental services of water and the atmosphere.

Tony Allan focuses his research on the social and political contexts which influence and usually determine water use and water policy. The research aims to explain why environmental and economic priorities fail to figure on the agenda of those using and allocating water. The research so far has deployed a wide range of environmental, economic, social and political theory.

The rich diversity of the theorisation is a feature of the international contribution of the Water Research Group at King's College London/ School of Oriental and African Studies in London. The research of the group recognises the underlying fundamentals of water in the hydrological cycle and the contributions and impacts of engineering interventions. The difficulties that water scientists and professionals encounter in gaining a place for their 'knowledge' in water policy discourses is a major current research theme. In the Middle East and North Africa – the regional focus of research – it has been shown that the water crisis has been effectively ameliorated through the availability of virtual water embedded in food traded internationally.

A second research theme is the role of non-water factors in solving water scarcity problems. Most water scarcity problems are solved outside the water sector. A third research focus is global water resource and the extent to which global resources will be sufficient to meet the needs of future populations.



Prof Tony Allan

The Middle Eastern and global issues have been addressed in three books:

- *The Nile: Sharing a Scarce Resource* [with Paul Howell], Cambridge University Press, Cambridge, 1995;
- *Water and Peace in the Middle East*: *Negotiating Resources in the Jordan Basin*, Tauris, London, 1996;
- *The Water Question in the Middle East*, Tauris, London, 2001.

In August 2009 Tony Allan was awarded the Stockholm Water Prize for his contribution to the re-conceptualisation of water security and the sustainable allocation and management of water.

Forthcoming Symposium

Contaminated Land: Contaminant Transport and Fate

RSC Environmental Chemistry Group

23 September 2009

Royal Society of Chemistry, Burlington House, Piccadilly, London

Exploring contaminant transport and fate in soil and groundwater with respect to contaminated land

Programme

10:00 Registration and coffee

Session 1

10:30 **Professor Andrew Hursthouse**, University of West of Scotland: *Contaminated land regulation: science-policy issues and pollutant dynamics*

11:15 **Professor Steven Banwart**, University of Sheffield: *Novel laboratory methods to study reactive transport of organic pollutants in groundwater*

12:00 - 12:45 Lunch

Session 2

12:45 **Mr Ian Martin**, Environment Agency: *Importance of chemical properties in estimating exposure*

13:30 **Dr Mike Rivett**, University of Birmingham: *The legacy of chlorinated solvents in contaminated land and groundwater*

14:35 -15:20 **Dr David Werner**, University of Newcastle: *Persistent organic contaminant availability in sediment: Improved risk assessment and novel remediation approaches*

15:20 Discussion and questions to speakers

16:00 Meeting close

Fee per delegate:

£100 – non-Environmental Chemistry Group (ECG) member

£50 – Environmental Chemistry Group member

£40 – RSC student member

The registration closing date is the 03 July 2009

Admission is by ticket only and places are limited, so please contact James Lymer at jlymer@wardell-armstrong.com (Wardell Armstrong LLP) initially to notify your interest in registering for the event. If places are still available then details of where to send the registration on p. 24 and cheque payment will be provided. For RSC members please provide your membership number in any correspondence.

Upon receipt of the registration slip and cheque payment, delegates will become registered for the event. Delegates may cancel their place at any time up to 3 weeks after the closing date and receive a 75% refund. After this time no refund is available to delegates for cancellations or non-attendance.

This event is supported by the Environment, Sustainability and Energy Forum of the Royal Society of Chemistry.

JAMES LYMER

ECG committee Member

Contact:

jlymer@wardell-armstrong.com

ROYAL SOCIETY OF CHEMISTRY, ENVIRONMENTAL CHEMISTRY GROUP

36th Annual General Meeting, 4 March 2009

and Distinguished Guest Lecture & Symposium on *The Future of Water*

Please tick the item(s) below as appropriate

I would like to attend: ☐ The AGM ☐ The Symposium

I enclose a cheque (payable to the RSC Environmental Chemistry Group) for:

☐ £25 registration fee (ECG members/non-ECG concessions)

RSC membership no:

☐ £50 registration fee (non-members of the ECG)

☐ I would like to attend as a retired RSC and ECG member

Name:

Address:

Email:

Please send completed form with payment to: Dr Leo Salter, Opie, Cornwall College, Pool, Redruth, Cornwall TR15 3RD leo.salter@cornwall.ac.uk Fax 01209 616230

ROYAL SOCIETY OF CHEMISTRY, ENVIRONMENTAL CHEMISTRY GROUP

Contaminated Land: Contaminant Transport and Fate, 23rd September 2009

Please tick the item(s) below as appropriate

☐ £40 registration fee (RSC Student Member)

☐ £50 registration fee (RSC ECG Member)

☐ £100 (Non-ECG Member)

RSC membership no if applicable:

Name:

Address:

Email:

Initially, please email James Lymer, Wardell Armstrong LLP (jlymer@wardell-armstrong.com) to notify your interest in registering for the event. If places are still available then details of where to send this registration slip and cheque payment will be provided.

Forthcoming Symposium

Atmospheric Chemistry Forum

RSC Environmental Chemistry Group

2nd April 2009

Royal Society of Chemistry, Burlington House, Piccadilly, London

The **Atmospheric Chemistry Forum** will be an informal afternoon meeting in Burlington House on 2nd April 2009.

This meeting is targeted primarily at PhD students and first appointment post-doctoral researchers who are carrying out research in atmospheric chemistry – interpreted in its broadest sense.

The aims of the meeting are:

- to provide a forum for delegates to discuss current research topics;
- to present their work to their peers, either as a 15 minute talk or as a poster presentation; and
- to exchange expertise and foster links between individual members of research groups.

Prof. Mike Pilling (Leeds University) will deliver the forum's invited lecture, and will review some of the current research efforts in atmospheric chemistry plus the key areas where knowledge desperately needs to be improved. There will also be a discussion/ question-and-answer session about careers in the field of atmospheric and environmental chemistry facilitated by an expert panel, who will include **Dr Jacqui Hamilton** (University of York), **Dr Adrian Kybett** (National Centre of Atmospheric Science and ECG committee member) and **Caroline Tolond** (the Royal Society of Chemistry's Advice and Guidance Services Manager).

Attendance at the forum is by prior registration (preferably by 31st January) and is free to RSC members (£35 for non-members). Priority will be given to PhD students and early career researchers. The forum is delighted to have been awarded an RSC Travel Grant which will enable the organising committee to assist with RSC student members' travel expenses. The forum's free registration and help with travel expenses therefore represents particularly good value to student members, including those who might wish to join the RSC in advance of the meeting. The forum's registration form and further details are available from www.rsc.org/ecg

Atmospheric chemistry is also a major activity within the **Gas Kinetics Discussion Group** (GKDG), particularly for laboratory-based studies of atmospherically important reactions & processes. Therefore we extend an open invitation to GKDG members to register for the forum.

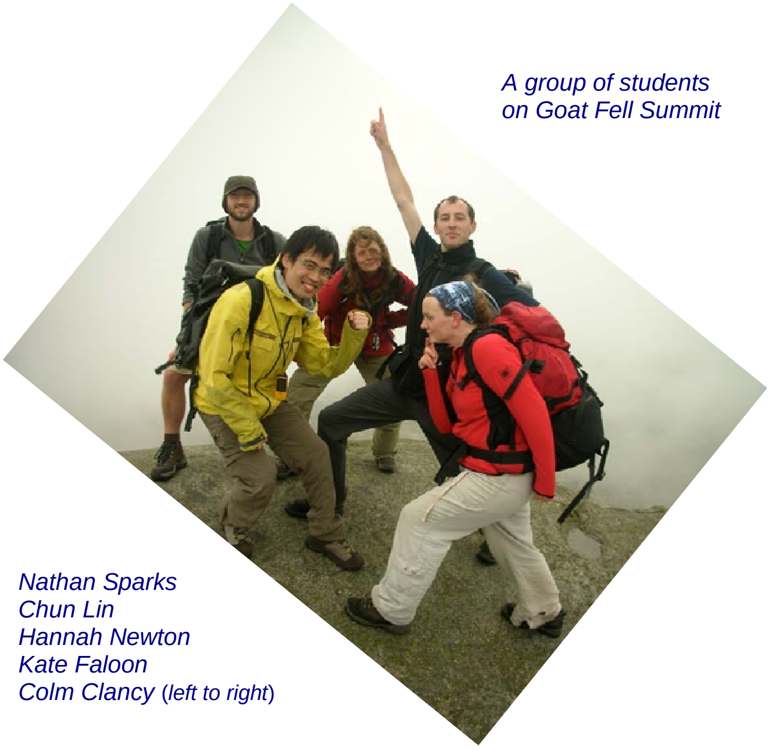
STEPHEN BALL and BILL BLOSS

Atmospheric Chemistry Representatives on the ECG committee.

Contacts: sb263@leicester.ac.uk or w.j.bloss@bham.ac.uk

'Is Goatfell higher when it rains?' and other interesting questions from the NCAS Summer School 2008

The annual National Centre for Atmospheric Science (NCAS) Atmospheric Measurement Summer School saw PhD students from the UK and overseas travel to the Isle of Arran in Scotland. The aim of the summer school was to introduce early stage PhD students to all aspects of meteorology and atmospheric science. A group of participants from Europe and the USA look back on their scientific experiences at this year's summer school.



A group of students on Goat Fell Summit

Nathan Sparks
Chun Lin
Hannah Newton
Kate Faloon
Colm Clancy (*left to right*)

The first half of the course consisted of a series of lectures covering a range of topics, from the chemical evolution and composition of the atmosphere to numerical weather prediction. The second part of the course consisted of a more practical approach – fieldwork was undertaken on Goatfell, the highest mountain on Arran; air samples were taken and analysed to determine the carbon monoxide profile of the mountain. Weather balloons were released twice daily, and weather forecasts produced each evening. The course ended with group presentations on a number of topics introduced throughout the week, some of which are discussed briefly in the rest of this article.

'Is Goatfell higher when it rains?'

To a good approximation, atmospheric pressure varies with height according to the hydrostatic

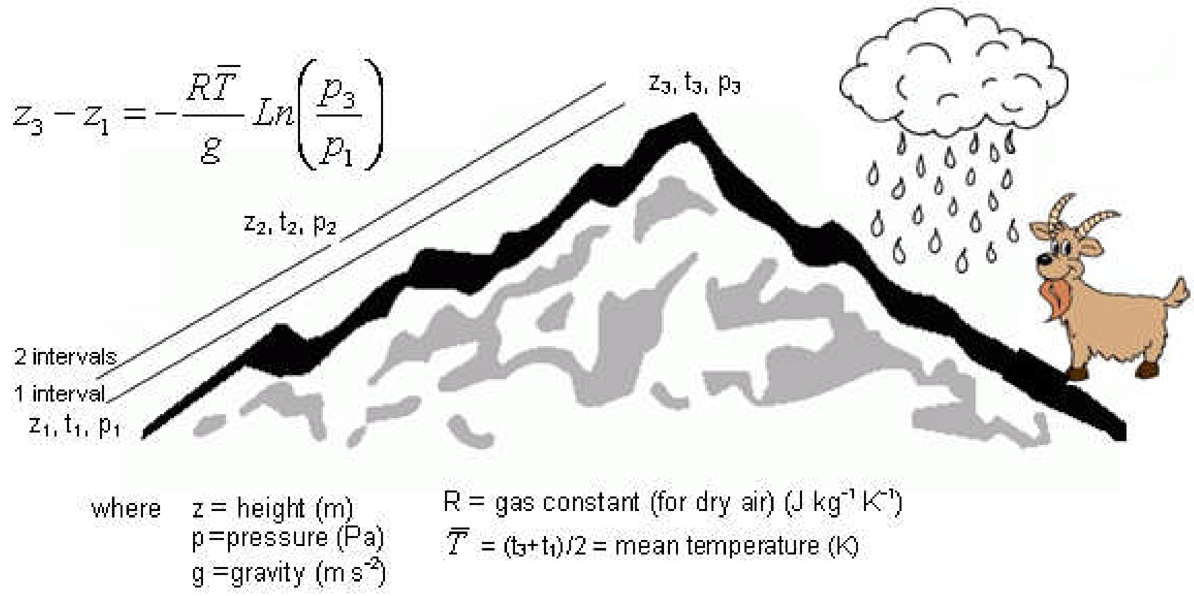


***Figure 1**: How the hydrostatic equation combined with the ideal gas law can be used to calculate the elevation if temperature and surface pressure are known*

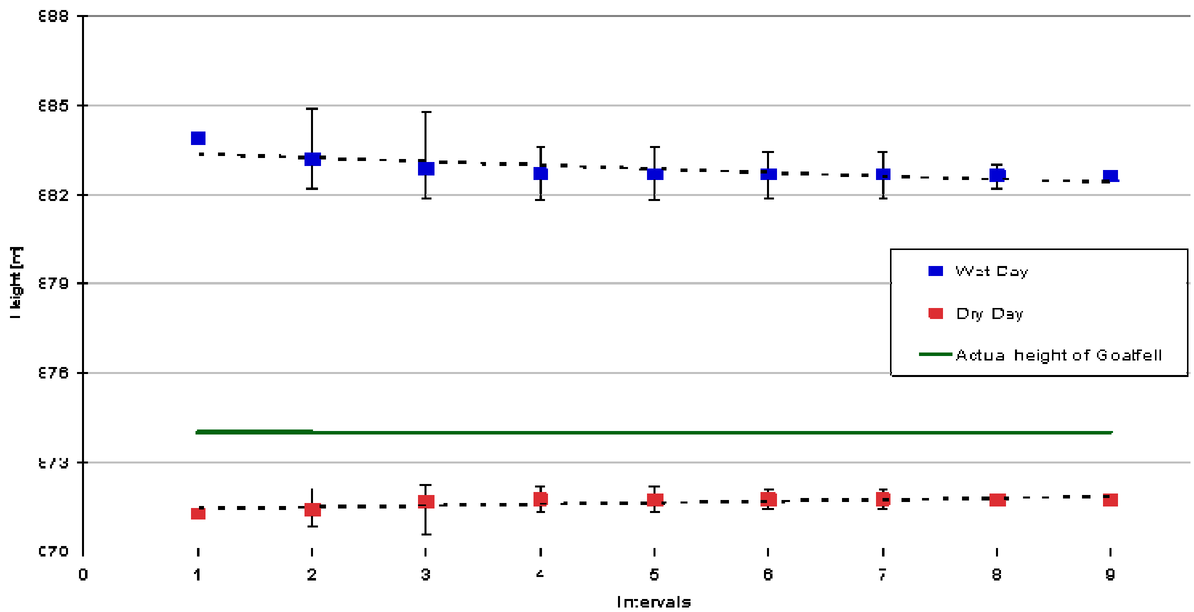


***Figure 2:** Altitude of Goatfell (metres) as calculated using the hydrostatic equation and the actual height as taken from the Ordnance Survey map. The altitude estimated for each interval is the average of all possible interval combinations, and error bars represent the max and min values calculated for each interval combination.*

equation (Houghton, 2002). By applying the ideal gas law to this equation it can be modified to show that the difference in height between two points is proportional to the logarithm of the ratio of their pressures. This information can be used to calculate the elevation at a given location from the temperature and surface pressure recorded at that location assuming no change in synoptic pressure during the measurement period (**Figure 1**).

On the NCAS field course, the elevation of Goatfell was calculated using the hydrostatic equation under dry and wet conditions (see **Figure 2**) and the effect of increasing the number of measurement intervals used was also investigated. The results show, as expected, that increasing the number of intervals increases the accuracy to which the hydrostatic equation can calculate a given altitude as the error involved using mean temperature is reduced. Furthermore the results suggest that, in line with popular student

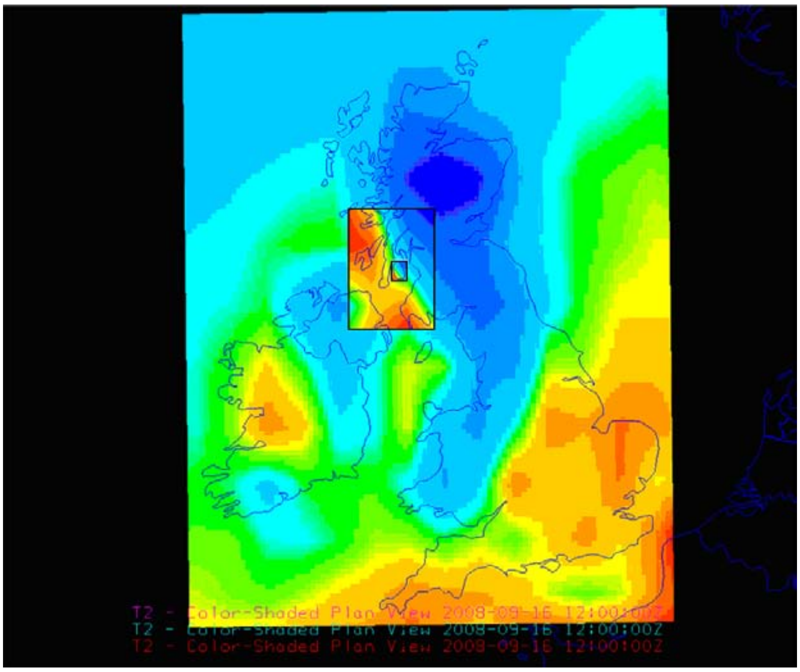


Figure 3: *Nested grids for the WRF forecasts*

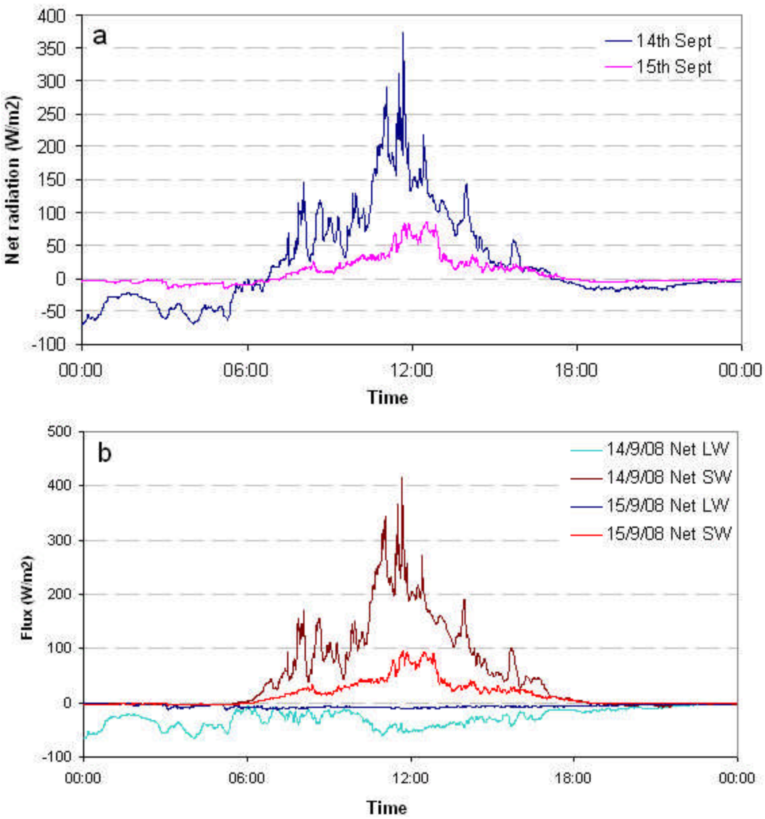


Figure 4: *Energy fluxes at Lochranza field centre, Isle of Arran, 14th and 15th September: (a) Net surface radiation; (b) Net long and short wave fluxes*

opinion, Goatfell is actually higher when it rains!

In all reality, the overestimation of elevation of Goatfell under wet conditions probably results from using the gas constant for dry air rather than wet. The value of R will decrease for wet air thus decreasing the calculated height of the mountain.

'It never rains on Arran, it pours …' at least according to the WRF model

The Weather Research and Forecasting (WRF) Model is a state of the art numerical weather forecasting model developed by a collaboration of US research institutions (further details available at http://www.wrf-model.org/). It has the ability to run with nested computational grids of varying resolution, allowing the user to produce detailed forecasts for a specific location. Throughout the NCAS field course the WRF model was run daily for the Isle of Arran. Three grids were used as shown in **Figure 3**. The outer grid covering the UK and Ireland had a resolution of 9 km, with 3 km for the intermediate domain and 1 km for the inner one. Initial and boundary data for the daily forecasts was taken from the National Centers for Environmental Prediction (NCEP) High Resolution Global Forecast System.

The models derive anticipated values of numerous meteorological parameters, including sea-level pressure, temperature, wind speed, potential vorticity and cloud cover. These provided a useful teaching tool and could be used when preparing forecasts. The most discussed WRF output was the precipitation for 14th and 15th September as it was on these days that fieldwork, including the ascent of Goatfell, would take place. The

Location	[CO]/ppb	Height/m	E([CO])/ppb
Seaside	26.79	1.00	2.93
Roadside	36.47	1.00	1.86
Roadside	25.61	1.00	3.30
Roadside	34.35	1.00	2.40
Hillside	26.26	101.00	0.37
Hillside	24.06	203.00	0.72
Hillside	25.36	306.00	1.36
Hillside	24.59	599.00	1.54
Hillside	27.52	704.00	2.32
Hillside	25.44	797.00	0.90
Hillside	26.71	448.00	1.17
Hillside	24.88	448.00	0.86
Hillside	25.58	448.00	0.43
Summit	189.85	874.00	1.78

Table 1: *Carbon monoxide concentrations measured at various locations around Goatfell, Isle of Arran, 14th -15th September, 2008*

model produced graphs that showed the expected rainfall accumulated over 2 hours, from a forecast initialised at 12 UTC on 13th September. WRF forecast that the 14th would be more suitable for outdoor activity, with dry weather expected. On 15th, a rainfall rate of roughly 2-4 mm per 2 hours was forecast. To compare the model data to actual observations a weather station was set up at the Lochranza field. As expected, the 14th was a dry day, while on 15th we see much wetter conditions, with recorded rainfall rates of between 1 and 4 mm/hour. So while this may have been a miserable day on Goatfell for some, it proved to be a success for the WRF forecasts.

Energetic Measurements

The input of energy to the Earth's surface and its subsequent conversion and partitioning into different forms of energy is described by the surface energy balance $R_n = G + H + LE$ (Houghton, 2002), where R_n is the net radiation input to the surface, G is the ground heat flux, H is the sensible heat flux and LE is the latent heat flux.

At the Lochranza field centre, the net radiation was measured by means of a radiometer and the ground heat flux using a heat flux plate buried beneath the surface. Analysis of the data collected for 14th and 15th September revealed a greater receipt of net radiation at the surface on 14th (see **Figure 4a**).

The net radiation describes the short wave (0.3 μm < λ < 2.0 μm) solar radiation received, absorbed and reflected at the surface and the long wave (3 μm < λ < 30 μm) radiation absorbed and emitted by both the surface and the atmosphere. When the net radiation fluxes shown in **Figure 4a** were decomposed into short and long wave components (**Figure 4b**), it was shown that on the 15th there was a lower net short wave and a higher net long wave flux than the 14th. These effects may be attributed to conditions being generally clear on the 14th, whilst the 15th was characterised by continuous cloud cover. The cloud present on the 15th is likely to have reflected and absorbed the incoming short wave radiation, thus reducing the flux at the surface. The stable net long-wave plot for the 15th implies that the atmosphere and surface are in radiative equilibrium, suggesting that the cloud layer is acting as a near-perfect black body at these wavelengths.

Profiling the CO concentration and … the hidden industry

Carbon monoxide (CO) is considered to be the most common atmospheric pollutant. The magnitude of CO concentrations is usually indicative of the air quality of a region. Major sources of CO include the burning of fossil fuels and biomass and the oxidation of methane (CH_4) and other hydrocarbons. Therefore, higher concentrations of CO are expected to be found near urbanized areas, whereas in rural regions the CO levels should be low.

Goatfell was climbed to collect whole air samples at various altitudes. A gas pump was utilized in order to collect a total of fourteen air samples; seven at approximately every 100 m increase in altitude, three at the roadside and at an altitude of around 500 m (for cluster analysis) and one at the seaside (as a background CO reading). The obtained air samples were analysed by gas chromatography (Heard, 2006). Having calibrated the gas chromatographer, we estimated the CO concentration in

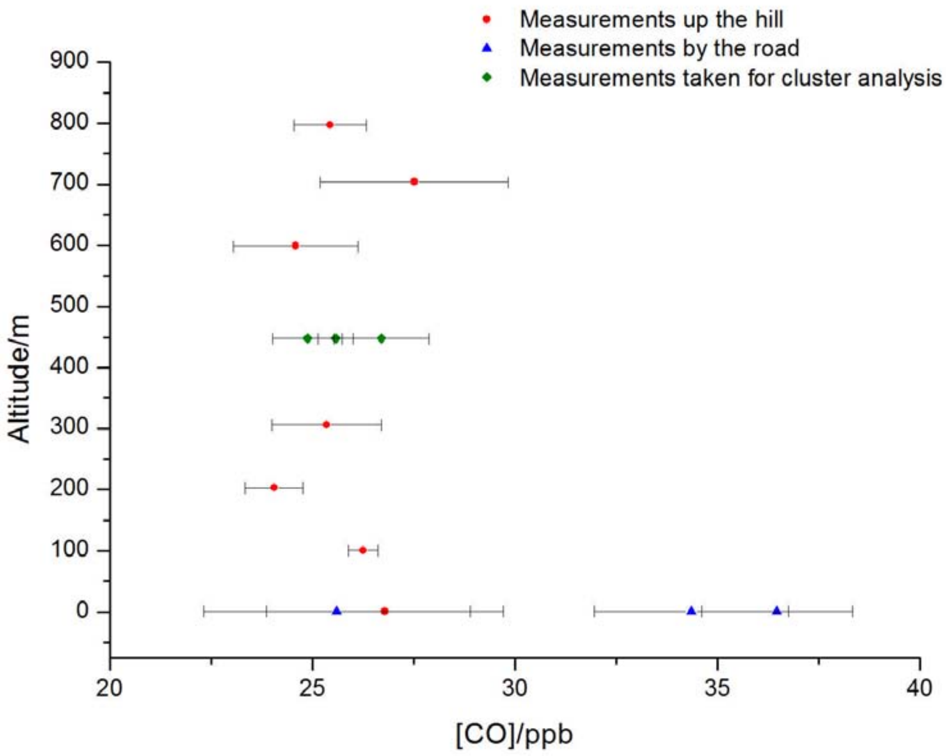


Figure 5: *The vertical profile of CO measured on Goatfell on 14th September 2008*

our collected air samples. **Table 1** summarizes the findings of our air sampling analyses.

As it can be seen in **Table 1**, the concentration of CO in air is generally negatively correlated with the altitude. Higher concentrations are found near the surface level e.g. roadside measurements. However, there is an outlier in the data – the measurement taken on the summit of Goatfell. This concentration is so high that it could only be found if measuring near the stack of a burning chamber. Since this is not the case at the top of the mountain, we decided to consider the corresponding air sample contaminated and thus, exclude this observation from the construction of the vertical profile of CO (**Figure 5**).

Figure 5 illustrates the vertical profile of CO. Higher concentrations can be found near the surface, where major sources of CO are present (road transport). As we move up to the summit of Goatfell, the concentration of CO appears to slightly decrease, somehow oscillating around a value of 26 ppb. The latter level of concentration should be attributed to the presence of a background CO concentration equal to 26 ppb. This is in good agreement with the CO concentration estimated from the air sample that was collected at the seaside, a site which was chosen as representative of background CO concentration.

References

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Meeting Report

NCAS Atmospheric Science Conference 2008

The NCAS (National Centre for Atmospheric Science) Atmospheric Science Conference for 2008, held in Bristol in December, highlighted the breadth of research carried out by NCAS, as **Kate Furneaux** reports.

NCAS Atmospheric Science Conference 2008: the three winners of the best student poster prize. From left to right: Paul Hardaker (Royal Meteorological Society), Tamsin Malkin, Marvin Shaw, Helen Atkinson and Leanne Marie (RSC). Tamsin Malkin: 'OH yields from gas-phase ozonolysis of isoprene'. Marvin Shaw (1st prize) : 'Links between inorganic and organic halogens in a sub-Arctic atmosphere'. Helen Atkinson: 'Investigating biological sources of iodine emissions in the sea-ice zone'

For the first time this conference was open to the whole atmospheric science community, resulting in a high attendance of early career scientists. A diverse range of scientific research was presented, ranging from highly specific laboratory-based kinetic measurements, to field measurements in the polar regions, to adapting to climate change. The message delivered by many throughout the conference is the necessity to understand the atmospheric system at many scales, and to integrate these processes fully.

The keynote speaker, **Professor Robert Watson** (Department for Environment, Food and Rural Affairs, Defra), allowed the audience the opportunity to reflect on:

- the impacts of climate change;
- the challenges facing the Government on mitigation options; and
- the scale of physical, technological and behavioural adaptation that can realistically be achieved.

Prof. Watson emphasized that scientists need to be able to distil results to policy makers, enabling high impact science that will be directly beneficial to society. Knowledge exchange between researchers and policy makers is essential.

A talk from **Dr. William A. Cooper**, NCAR (National Centre for Atmospheric Research, USA), addressed the future direction of airborne measurements. An exciting project is the Pole-to-Pole Observations (HIPPO) of Carbon Cycle and Greenhouse Gases Study, which began in January 2009. Global airborne measurements of a range of important greenhouse gas concentrations will be made over a two-year period. The results will be closely coupled to model analysis. Dr. Cooper emphasised the importance of interactive research internationally, especially for planning global scale and remote-based operations to maximize results.

Indeed, many field campaigns already utilize international collaboration. The Cape Verde Atmospheric Observatory is one example of this. The observatory, which began measurements in

November 2006 and is run by **Dr Lucy Carpenter's** group at the University of York, provides long term gas and aerosol measurements carried out by research groups from the UK and Germany. Additionally, intensive measurement campaigns have included collaborators from the USA. This site is now providing interesting long term measurements at an analogous open ocean, clean tropical location. Recent findings have highlighted the importance of halogen chemistry in quantifying ozone depletion (Read et al, 2008).

The submission of nearly 200 abstracts revealed the breadth of research of the atmospheric science community. **Paula Gorrotxategi Carbajo** (University of Bristol) reported on the detailed work of her group to measure the absorption cross-section of formaldehyde, which is an oxidation product of many volatile organic compounds (Gorrotxategi Carbajo et al, 2008). The high resolution (0.005 nm) absorption cross-section and quantum yield measurements result in higher photolysis rates of HCHO. These data will be utilised in atmospheric chemistry modelling.

Another important laboratory-based study was highlighted by **Tamsin Malkin** (University of Leeds), who won a poster prize for the work she presented on the measurement of OH yields from the ozonolysis of alkenes. These results are essential to improve understanding of lesser known sources of OH, which is the most important day time oxidant in the atmosphere.

Instrument development is core to NCAS activities. **Clare Bell** (University of Oxford) presented work on the development of a Noise Immune Cavity Enhanced Optical Heterodyne Molecular Spectroscopy (NICE-OHMS) for the determination of speciated peroxy radicals. This is a novel instrument to measure the HO_2 radical and methane. The advantage of this technique is that it does not require calibration but sensitivity is not yet low enough to enable field deployment.

Field measurements feature highly in atmospheric chemistry research. In spring 2008, scientists from the UK, Ireland and Canada were involved in the COBRA (impact of COmbined Iodine and Bromine Release on the Arctic atmosphere) field campaign at Hudson Bay, Quebec, Canada. Two PhD students who worked on the project, **Helen Atkinson** (British Antarctic Survey) and **Marvin Shaw** (University of York) won poster prizes for their work during COBRA. Marvin and his group made GC-MS measurements of reactive halocarbons in the polar boundary layer. Helen Atkinson's work focused on investigating the biological sources of iodine emissions in the sea-ice zone. She aims to determine if brine channels are involved in the source of iodine release. The combined results from COBRA will further the understanding of halogen chemistry in the Arctic, which is currently understood to a much lesser extent than Antarctica.

In combination with laboratory measurements and field observations, climate models are used to predict climatic trends. Dr. **Len Shaffrey** (NCAS Climate, University of Reading) highlighted the importance of predictions of rainfall, flooding, drought and high impact weather to inform adaptation strategies. The HiGEM model has been developed to provide high resolution climate modelling (1.25° longitude × 0.83° latitude) compared to the models used in the IPCC 4th assessment report. These predictions are required at a regional scale, to determine the level of adaptation required to deal with climate change. This issue is also being addressed in the USA.

Greg Holland (NCAR) highlighted the need for decadal, regional climate predictions. At NCAR, they aim to use a nested regional climate modelling approach to provide the information needed for policy makers.

A combination of laboratory measurements, field observations and atmospheric modelling is required to provide the answers necessary to enable adaptation and successful mitigation to combat climate change.

The NCAS conference highlighted the exciting advances that are being made in these areas worldwide. Integration of results throughout the community is vital. It was clear that dissemination of the results to enhance understanding of these global issues to government, businesses and the public is essential.

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A focus on atmospheric science for the RSC's Environment, Sustainability and Energy Forum in 2009

The Environment, Sustainability and Energy Forum (ESEF) was formed in 2003 in order to support, manage and co-ordinate more effectively on behalf of the members, and in line with the RSC Charter, the various important activities that take place related to environmental chemistry, toxicology, water, green chemical technology, energy and sustainability.

2008 Has been a year of change with Dr Andy Smith taking over as ESEF Chair and myself as the new RSC Environment and Energy Policy Manager. We currently have activities spanning all of ESEF's priority areas, including a focus on sustainable water management, the strategic importance that energy storage will play in renewable electricity generation and our future transport needs, and the promotion of green chemical technology within the pharmaceutical industry. We try to influence government policy by direct communication with government ministers (though the RSC parliamentary team), by answering consultations and at the grass routes by working with funding bodies and industrial partners to try and influence the need for increased and continued funding throughout the chemical sciences.

I hope 2009 will be even more successful with new projects getting underway. In particular ESEF is keen to increase the understanding of the chemistry of climate change with a particular focus on atmospheric science. This is an area that has been slightly in the background of the RSC, as was highlighted by our recent road mapping exercise, but we are keen for this to become a more prominent focus for ESEF activities over next couple of years. Indeed the increasing importance of environmental chemistry is being recognised throughout the RSC with the launch this year of the new RSC Journal "Energy and Environmental Science" and a revamp of the RSC awards to include our own high level "Environment Prize" and the "ESEF early career award". These will be presented for the first time in 2009 and I feel it will be an excellent opportunity to recognise the high level of research that occurs in the UK in relation to sustainable and environmental chemistry. Finally I would just like to point all members who are interested in ESEF activities to our web pages: www.rsc.org/ESEF and if you would like to give any feedback or indeed become more involved in any of ESEF activities please email me at milsome@rsc.org

Dr Elizabeth Milsom, RSC Environment and Energy Policy Manager

ELIZABETH MILSOM

Environment and Energy Policy Manager

Geoscale engineering to avert dangerous climate change

In an introduction to a thematic issue of Philosophical Transactions of the Royal Society A devoted to geoengineering solutions for ameliorating climate change, the two editors, Brian Launder and Michael Thompson, note that it is now recognised that the developed world is struggling to meet its carbon-reduction targets, while emissions by China and India have soared. Meanwhile, signs suggest that the climate is even more sensitive to atmospheric CO_2 levels than was previously thought.

Frustrated by the delays of politicians, scientists have for a number of years been proposing major 'last minute' schemes that might be needed if it were suddenly shown that the climate was in a state of imminent collapse. These geo-scale interventions are undoubtedly risky, but the time may come when they are universally perceived to be less risky than doing nothing.

For these reasons, it seemed an appropriate time to review these macro-engineering options. Emphasis was given to strategies for carbon sequestration, and albedo management to reduce the net amount of solar energy impacting and being retained by the Earth.

Web link: Geoscale engineering to avert dangerous climate change http://publishing.royalsociety.org/index.cfm?page=1814

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Reframing the climate change challenge in light of post-2000 emission trends, Kevin Anderson, Alice Bows

A geophysiologist's thoughts on geoengineering, James Lovelock. (An extended extract from Professor Lovelock's article is reproduced on pp 9-13 of this issue of the ECG Bulletin.)

Coping with carbon: a near-term strategy to limit carbon dioxide emissions from power stations, Paul Breeze

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Royal Society launches study on geoscale engineering

Following on from the publication of a thematic issue on 'Geoscale engineering to avert dangerous climate change', published in *Philosophical Transactions of the Royal Society A*, 2008, volume **366**, pp 3841-4056, and the interest generated by this review, the Royal Society announced in October 2008 that it was launching a major new study of planetary geoengineering schemes.

The study will look at a range of ambitious proposals that have been receiving increasing attention and consider whether they could be feasible or effective. It will also look at the environmental and social impacts and any other possible unintended consequences of these schemes.

Proposals to intervene in the Earth's natural climate system to help tackle man-made climate change include placing giant mirrors in space to reflect sunlight away from the Earth. It has also been suggested that releasing tiny particles into the upper atmosphere could help cool the climate by reducing the amount of the sun's energy that reaches the Earth's surface. Other scientists have proposed fertilising the oceans with nutrients, such as iron, to promote blooms of phytoplankton which would soak up carbon dioxide from the atmosphere.

The chair of Royal Society working group that will undertake the study, Professor John Shepherd, said: "Some of these proposals seem fantastical, and may prove to be so. Our study aims to separate the science from the science fiction and offer recommendations on which options deserve serious consideration."

"We need to investigate if any of these schemes could help us avoid the most dangerous changes to our climate and to fully understand what other impacts they may have."

"Whatever solutions technology may offer us in the future, it's clear that the need to cut emissions of greenhouse gases into the atmosphere is now more urgent than ever."

The Royal Society report is expected to be published in the middle of 2009. Individuals and organisations that are interested in submitting information to this study should consult the website: http://royalsociety.org/page.asp?id=2556

RSC Library News

The RSC library may be closed for a year (until September 2009) to visitors in person, but members' information needs will continue to be supported wherever they are 24/7 through the RSC Virtual Library, the Chemical Enquiries Help Desk.

Topics covered by recent enquiries include:

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The ECG *Bulletin* is printed on paper made from wood pulp sourced from sustainable forests, and is suitable for archival storage. This issue of the ECG *Bulletin* was printed by Sureprint, 1 Eastern Road, Haywards Heath, West Sussex RH16 3NG Tel: 01444 456673.