Sirius debate  •  Mycology against malaria  •  Deep ocean hot springs  •  Sinkholes  •  ECN
About us

NERC – the Natural Environment Research Council – is the UK’s leading funder of environmental science. We invest public money in cutting-edge research, science infrastructure, postgraduate training and innovation.

Our scientists study the physical, chemical and biological processes on which our planet and life itself depends – from pole to pole, from the deep Earth and oceans to the atmosphere and space. We work in partnership with other UK and international researchers, policymakers and business to tackle the big environmental challenges we face – how to use our limited resources sustainably, how to build resilience to environmental hazards and how to manage environmental change.

NERC is a non-departmental public body. Much of our funding comes from the Department for Business, Innovation and Skills but we work independently of government. Our projects range from curiosity-driven research to long-term, multi-million-pound strategic programmes, coordinated by universities and our own research centres:

British Antarctic Survey
British Geological Survey
Centre for Ecology & Hydrology
National Oceanography Centre
National Centre for Atmospheric Science
National Centre for Earth Observation

Editors
Adele Walker  01793 411604  admp@nerc.ac.uk
Tom Marshall  01793 442593  thrs@nerc.ac.uk

Science writers
Tamara Jones, Harriet Jarrett, Alex Peel

Design and production
Candy Sorrell  01793 411518  cmso@nerc.ac.uk

Contact us
To give us your feedback or to subscribe email: requests@nerc.ac.uk or write to us at Planet Earth Editors, NERC, Polaris House, North Star Avenue, Swindon SN2, 1EU.
NERC-funded researchers should contact: editors@nerc.ac.uk

Planet Earth is NERC’s quarterly magazine, aimed at anyone interested in environmental science. It covers all aspects of NERC-funded work and most of the features are written by the researchers themselves.

For the latest environmental science news, features, blogs and the fortnightly Planet Earth Podcast, visit our website Planet Earth Online at www.planetearth.nerc.ac.uk.

Not all of the work described in Planet Earth has been peer-reviewed. The views expressed are those of individual authors and not necessarily shared by NERC. We welcome readers’ feedback on any aspect of the magazine or website and are happy to hear from NERC-funded scientists who want to write for Planet Earth. Please bear in mind that we rarely accept unsolicited articles, so contact the editors first to discuss your ideas.
In this issue

Summer 2014

12 Getting ready for the next big one
Is Istanbul ready for a major earthquake?

14 Data crunching in space
How better image processing can help protect a warming Arctic.

16 Mission to ‘Mars’
Learning to live and work on the Red Planet – in Utah.

18 Mycology against malaria
Fungus offers new hope of controlling disease.

21 Sex & bugs & rock ‘n roll
Taking research on the road to Britain’s music festivals.

22 The death of the Sirius debate
Volcanic research settles a 30-year Antarctic controversy.

24 Hot mud – cold seeps
Probing the life around enigmatic deep-sea vents.

26 It’s a microbial world
What have microorganisms ever done for us?

28 Taking the environment’s pulse
Looking back on two decades of the Environmental Change Network.

30 That sinking feeling
Why did so many sinkholes appear across the UK last winter?
Editorial

We take you one step beyond in this edition of Planet Earth, with a trip to Mars – or somewhere a bit like it. PhD student Michaela Musilova shares a day in her life as a virtual astronaut, enjoying – or possibly suffering – the rigours of life in close quarters with a team of researchers to see what the life scientific might be like on the Red Planet.

Interplanetary exploration is all well and exciting, but other articles here deal with subjects of more immediate concern, from how scientists are trying to protect Istanbul from the risk of the first ‘million-death quake’ to how fungus could help contain the spread of disease.

Strange earth movements surprised many people across the UK this past winter, as heavy rains increased the incidence of sinkholes – literally in some people’s back yards. Sue Nelson found out more when she spoke to geologists from the British Geological Survey about this startling phenomenon.

After detours through Antarctica and the music festivals of Britain, Christine Campbell take us – Alice in Wonderland-like – into the world of microbes. Important for many diverse areas of research and innovation, they’ve even made a glowing contribution to the arts.

Organic farming boosts biodiversity

Analysis of 94 earlier existing studies by a team at the University of Oxford concluded that organic farming methods increased the number of species on average by 34 per cent – an effect that’s been stable over three decades and shows no sign of diminishing.

But this is only true of farms in temperate climates – there’s not yet enough research to show if the effect is the same in warmer climates. ‘Our study shows that organic farming can yield significant long-term benefits for biodiversity,’ says PhD student Sean Tuck, lead author of the paper which appeared in Journal of Applied Ecology. ‘Organic methods could go some way towards halting the continued loss of diversity in industrialised nations.’

Plants saw the greatest increase, with the number of species present increasing by around 70 per cent. Pollinators came second, with half as many species again on organic farms, while birds, arthropods and microbes also did well.

The benefit to biodiversity seems to be greater in intensively farmed regions, particularly on organic farms surrounded by arable land. So it could be that having a few organic farms scattered around the landscape could benefit the intensively-cultivated farms in between by providing islands of biodiversity to nurture valuable organisms like pollinators and predators that keep pest numbers down.

But, says Tuck, it’s also true that intensive farming methods may damage the biodiversity nurtured on the organic farm. For instance large doses of pesticides can affect bees and other pollinators on nearby organic farms as well. ‘The effect goes both ways,’ he says. ‘It depends on the scale you are looking at – a single isolated organic farm is likely to see more species, but at the landscape level the overall impact is much less clear.’
Seashells provide million-year-old weather report

New research, published in Earth and Planetary Research Letters, led by scientists from the University of Cambridge, used plankton – tiny bugs, whose shells litter the ocean floors. By drilling into the seabed scientists can extract shells from plankton which lived millions of years ago.

‘The shells we used are of a type of plankton called foraminifera. They’re only about one tenth of a millimetre across and have been around over 150 million years, so we get a really well-preserved record of them in marine sediments going back tens of millions of years,’ explains Oscar Branson, a PhD student at the University of Cambridge and lead author of the study. ‘Recently people have been analysing them for climate records, but now we realise they’re more complex.’

As plankton grow they build a bit more onto their shells every day by turning elements in the sea water into harder minerals and adding them on. The impurities in the shell depend on what was in the sea water as the plankton grew, so these million-year-old shells can give us an almost daily snapshot of the chemistry of the oceans as it was when they were still alive.

‘We realised plankton have these growth bands, like tree rings, which we thought might tell us something in more detail. It turns out these bands are produced almost daily so you may one day be able to get a five-day weather report by looking at them,’ Branson says.

The team used a synchrotron in California to study the shells, using charged particles to study the structure of the shells at a minute scale. The analysis revealed how much magnesium was in each growth band compared to other chemicals.

‘The concentration of magnesium changes depending on the temperature of sea water; so by finding out how much there was in the shell it should allow us to find out the temperature of sea water virtually each day for the last 150 million years,’ says Branson.

The intricate structure of plankton shells provides new opportunities to chart complex changes in climate. X-ray radiographs of plankton shells measured at Diamond Light Source, UK.

Whales counted from space

A team at the British Antarctic Survey has conducted a proof-of-concept study to see whether satellite images taken using a wider spectrum of light could replace traditional methods for counting whales.

The system could revolutionise the way scientists estimate whale populations and help focus conservation efforts.

‘Whales are notoriously hard to study, and especially to count,’ says Dr Peter Fretwell, lead researcher on the project which appeared in PloS ONE. The traditional method is to stand on the bridge of a boat and count whale blows or to take aerial surveys, but those methods are inefficient and inaccurate or expensive to conduct over a large area.’

The team used high-resolution satellite images of Peninsula Valdes in Argentina to develop a system to automatically identify and count southern right whales.

Hunted to near-extinction, southern right whales were chosen because the characteristics that make them easy to hunt – they’re big, slow and spend lots of time near the surface – also make for great satellite images.

Satellites capture more wavelengths of light than a regular camera, from infrared through to far blue. ‘The far blue light isn’t absorbed like longer wavelengths are,’ explains Fretwell. ‘So it allows us to see about 50 feet into the water column.’

Using a single image of the southern right whales’ breeding ground, the team found 55 probable whales, 23 possible whales and 13 sub-surface features through a manual search. When they used image-processing software to do the search it identified 89 per cent of the whale shapes.

‘The automated process will still need some user input, but by processing multiple images and taking advantage of improving satellite technology we might be able to start counting whales across the entire Southern Ocean,’ says Fretwell.
A new study has brought into question the long-standing theory that people transported the Stonehenge bluestones from Wales to Wiltshire.

The bluestones, the smaller stones at Stonehenge, originate from the Preseli Hills in Wales and are thought to have been transported to Salisbury Plain over 4000 years ago.

The chemistry of the rocks varies depending on their exact source and by confirming that source researchers hope to help answer the long-standing question of how around 80 of these bluestones, weighing up to three tonnes each, were transported 250km from south-west Wales to Wiltshire.

‘Many people think humans transported the stones down from the Preseli Hills and then up the Bristol Channel on rafts,’ says Dr Richard Bevins of the National Museum of Wales, who led the research.

But another school of thought says these rocks are glacial erratics, transported to what is now Salisbury Plain by ice, and so were available locally to the monument builders.

Once the source of the stones is confirmed archaeologists can look for evidence of people working the source stones.

Using a new method of identifying the chemical make-up of the rocks, the team believes they have now identified Carn Goedog as the source of at least 55 per cent of the spotted dolerite bluestones at Stonehenge, and another outcrop, Craig Rhos-y-felin, as the source of another type. Both outcrops are on the northern side of the Preseli Hills. If this is correct it calls into question the idea of the stones being transported by rafts down to the Bristol Channel.

‘The rocks would have had to be dragged up the hills, across the summits and back down again before they even reached the waterways. It’s just not likely,’ Bevins concludes.

Individual ecosystems survived even the largest known mass extinction event, according to a new study, published in Nature Geoscience.

The research shows that ecosystems continued to function after the Permian geologic time period, 252 million years ago, which saw a change in climate so severe that Earth lost 95 per cent of its species.

‘Biodiversity is composed of two things: its richness – the number of species – and the diversity of its ecosystems. This isn’t about the numbers of species that went extinct,’ explains lead researcher Professor Richard Twitchett of Plymouth University.

The researchers used a newly available online database of the fossil record to build their own lists of species that went extinct after the Permian. Then the pair studied how each species contributed to its ecosystem by assessing how it fed, where it lived and how it moved.

Crucially they also included species that were likely to have been around at the time, even though there is no trace of them in the rocks.

The pair then studied how the changing climate affected those ecosystems globally and regionally.

‘When we looked at the ecology we saw that, of the groups that drive an ecosystem’s functions, none were completely eliminated; the survivors fulfilled all of the roles needed in the ecosystem,’ Twitchett continues.

‘There was always one animal somewhere on the planet doing what it needed to do to make the ecosystem function.’

‘The end of the Permian was a time of global warming, and also saw the biggest extinction we know of from the fossil record, so perhaps the fact that no single ecological group was eliminated gives us a cause for optimism. It tells us that modes of life are very resistant and we would have to decimate things significantly to break them down,’ says Twitchett.
New test for high-speed rail vibration

Scientists have developed a model to predict how much vibration a new high-speed railway would cause and the effect this could have on people living near the railway line.

Vibrations can be transmitted into walls and through floors of nearby buildings. While they would probably be too small to damage buildings, they could disrupt the work going on inside, for example affecting sensitive hospital equipment. And as more high-speed lines are built they will inevitably affect more people.

Assessing these vibrations on the ground would require expensive and impractical tests, but scientists from Edinburgh and Belgium think they have found a way of taking accurate measurements for free.

‘The big challenge in this area is that vibration assessment is very computationally demanding, so previously some models took days or weeks,’ explains Dr David Connolly of Heriot-Watt University, lead researcher on the project. ‘My tool is instant.’

The new tool, described in Soil Dynamics and Earthquake Engineering, uses existing data on soil properties from NERC’s British Geological Survey. The team tested their model on high-speed lines in Belgium and on HS1, the high-speed line running through the Channel Tunnel.

Ship noise changes fish behaviour

Fish that eat near busy shipping lanes may not be as efficient at foraging for food, say scientists investigating the effect of elevated noise levels on marine life.

In the new study, published in Animal Behaviour, researchers led by Irene Voellmy of the University of Bristol, played recordings of ship noise to sticklebacks and minnows in tanks as they tried to eat.

Ship noise is one of the most common human-generated noises in aquatic environments and its potentially harmful effects are of growing concern, especially on fish that are economically valuable like eel and sea bass.

‘Both fish showed increased stress-related behaviour in response to the noise. They startled more often and consumed fewer water fleas. But there were differences between the two species; sticklebacks made more foraging errors, mostly because they attacked non-food items instead of water fleas, and minnows spent more time interacting with a companion in the tank or stopped moving more often,’ says Voellmy.

In the real world, lack of food could impair growth rates, survival and breeding success, and more foraging errors may mean the fish risk poisoning themselves.

The team thinks there could be three reasons for the behaviour change: stress, cognitive impairment or distraction.

New planes could cut aviation carbon emissions

Replacing older aircraft in a fleet with newer models could lead to substantial cuts in aviation carbon emissions, according to new research.

The study, published in Transport Policy, assessed the potential impact of using carbon tax revenues to subsidise the replacement of older aircraft. This could reduce aviation emissions by up to a third by 2050, relative to business-as-usual.

‘Neither scenario is realistic in practice,’ says Dr Lynnette Dray from the University of Cambridge, who led the study. ‘But it’s a useful exercise in demonstrating the effect that aging technology is having on aviation emissions.’

Aviation emissions are still growing, partly due to the long lifetime of aircraft which are designed to be in use for 30 or more years. So new, cleaner technology is slow to take effect.
Solar activity linked to changes in ocean currents and climate

A striking drop in solar activity was probably responsible for a long spell of harsh winters in northern Europe from around 1400 to 1800 known as the Little Ice Age, say scientists. The findings mean an imminent quiet period in the Sun’s activity predicted by some scientists could lead to severe winters in Britain.

Researchers found that lower solar activity can encourage high-pressure blocking systems to develop over the North Atlantic, which stop warm tropical winds reaching Europe. This leads to cold winters like those of 2010 and 2013. This is the first time anyone has shown how a drop in the Sun’s energy can lead to changes in the climate around the North Atlantic. The findings are published in Nature Geoscience.

Researchers analysed the chemical composition of fossilised microorganisms called foraminifera from a sea-floor sediment core to investigate how the Gulf Stream differed from today.

‘We found big and abrupt changes in temperature and salt concentrations in the sediment core, which matched changes in solar activity,’ says Dr Paola Moffa-Sánchez of Cardiff University, who led the study.

Seaside swimmers face hidden risks

The greatest risk of being dragged out into deep water is when waves are small and the tide is low, new research has revealed.

The study, carried out on beaches throughout Devon and Cornwall, UK, says dangerous rip currents are at their most potent in small but long waves caused by distant storms.

Its authors, from Plymouth University, are working in partnership with the RNLI and the Met Office to develop a rip current forecast, in the same vein as the pollen and UV hazard indexes.

‘Rip currents are the single greatest hazard on a surf beach,’ says Dr Tim Scott, who led the study.

Rip currents are caused as water trying to make its way out to sea is pushed back towards the shore by waves. They can be powerful enough to drag even the strongest swimmers out to deep water.

Scott says the danger is down to a combination of sea conditions and human behaviour.

‘You can be swimming around in no apparent danger for 10 or 15 minutes, and then there’ll suddenly be a group of swell waves from storms out in the Atlantic, and it is under these pulsing rip current conditions that people tend to get into trouble.’

‘When the waves are high the hazards are more obvious, but on calmer days there are likely to be more inexperienced bathers in the water and what we’ve shown is that the rip currents themselves can actually be more dangerous.’
Effects of winter storms under scrutiny
A 12-month project will assess how the barrage of devastating winter storms affected coastal communities in south-west England.

In winter 2013-14 the coast was battered by an unprecedented run of storms including one dubbed Hercules, which brought 8-metre waves to Land’s End and parts of Dorset.

Researchers will measure the storms’ effects on beaches, cliffs and sand dunes at more than 25 sites, as well as mapping changes to the underwater landscape at a further two.

The work will feed into a Google Earth-based storm impact map and will help people better prepare for these events in future, as well as informing long-term coastal management.

Agreement signed with Shell
In February NERC signed a Memorandum of Understanding (MoU) initiating a strategic partnership with global energy company Shell.
NERC-funded research produces a wealth of data, knowledge, tools and expertise, and a central part of its remit is to work with businesses, policymakers and third-sector organisations to help them find and use the research they need. Strategic partnerships are one way of linking the needs of one particular science user with long-term research – as a publicly-funded body, however, all the outputs of NERC science are available to everyone.

New programme will support climate change negotiations
Climate change minister Greg Barker announced a two-year programme in March which will provide robust evidence for international policy discussions in the run-up to the UN Framework Convention on Climate Change 2015 conference (COP21).

Funded by Living with Environmental Change partners the Department for Energy and Climate Change, Defra and NERC, AVOID 2 will focus on six research areas to help interpret the implications of any new global agreement.

NERC has contributed £100k to the £1.45m research programme, which will be delivered by a multi-disciplinary consortium led by the Met Office Hadley Centre.
Scientists have brought material from an Antarctic moss bank back to life after being frozen for 1600 years in permafrost.

No one has ever recorded a plant or animal growing again after being frozen for so long. Until now, the physical limit was thought to be just 20 or 30 years for complex life.

If the moss could rejuvenate after even longer, up to tens of thousands of years, it might provide a polar refuge from which life could recover after an ice age.

Scientists from NERC’s British Antarctic Survey (BAS) and the University of Reading published the discovery in Current Biology.

“We brought it back to the lab in Reading to thaw, and kept them in a plant incubator at around 17-18°C, which is similar to the temperature the growing surface can experience in their natural habitat in the summer,” says Professor Pete Convey of BAS, who led the collaboration.

“Incridibly, the moss at the bottom of the core, which was dated at over 1500 years old, grew back at almost exactly the same time as the newer material at the top.’

Complex life forms can shut down their respiratory systems for ten years or more but their cells get damaged over time and it was thought that this would limit the survival of complex organisms to no more than a few decades.

Nobody can explain yet how the mosses are able to rejuvenate after so long.

There are growing concerns about the release of greenhouse gases such as carbon dioxide and methane from melting permafrost in the Arctic tundra.

But mosses are an effective absorber of carbon dioxide, and if they can bounce back strongly as the permafrost melts they may help to offset some of those extra greenhouse-gas emissions.

NERC is to commission a new polar research ship that will enable the next generation of world-leading polar marine science. The Chancellor of the Exchequer, the Rt Hon George Osborne MP, announced in April that the government has earmarked more than £200 million of capital investment for the new UK polar flagship. NERC’s British Antarctic Survey will run the ship for the benefit of the whole UK research community; it should be ready for its first scientific mission by 2019.

The icebreaker will provide a world-leading platform letting UK researchers work in the coldest, most remote parts of the planet and collect data that will lead both to major scientific breakthroughs and to significant economic and societal benefits, particularly in areas like understanding the progress of climate change.

Incorporating a helideck and hangar, flexible laboratory space and accommodation for up to 60 polar scientists and technicians, it will play a key role in helping us understand the Arctic and Antarctic – two of our planet’s fastest-changing regions.

The flagship will have better ice-strengthening and more endurance than NERC’s current two polar vessels, the RRS James Clark Ross and the RRS Ernest Shackleton. This will allow it to set off on research cruises earlier in the year, and stay at sea for up to 80 days compared to their 60.

Longer voyages starting earlier in the season will in turn open up new locations to the scientific community, marking a major advance in UK scientists’ ability to carry out research in these vital polar environments and understand how they are changing.
A new generation of drugs could help combat the growing number of bacterial diseases that are becoming resistant to antibiotics, a study reveals.

Diseases that are currently curable could become life-threatening if they evolve resistance to existing treatments. Antibiotics work by killing the bacteria, or stopping their growth, so any bacteria that are resistant to the drug will thrive, giving them an advantage over non-resistant ones. This advantage means the resistant bacteria are more likely to spread and become dangerous.

Researchers from the University of Edinburgh and University of Nottingham have been studying anti-virulence drugs, which target the part of the cell that makes people ill but still allow the bacteria to grow, so resistant strains don’t have an advantage over non-resistant ones.

PhD student Richard Allen of the University of Edinburgh and colleagues carried out a review, published in *Nature Reviews Microbiology*, of work into anti-virulence drugs over the past five years, to assess whether or not these drugs are as evolution-proof as some claim.

Allen suspects these drugs are at least 20 years away from being commercially available. But reviews like this will help developers to build versions of these drugs that are the most likely to prevent the spread of resistant bacteria.

Tawny owls face long-term decline because environmental change is dampening the population cycles of their favoured prey, a new study has shown. If this continues, they will slowly die out over the coming decades.

Scientists analysed 27 years of data on owl populations and breeding patterns in Kielder Forest in Northumberland alongside the results of an earlier study. The latter showed field vole populations across Europe, which until recently fluctuated from year to year, are becoming much more stable.

Voles are the cornerstone of the tawny owl diet – they’re so important that the owls often can’t breed unless their population grows dense enough. So owls are better off with some bad years and some plentiful ones than with a constant mediocre vole supply; the latter means few will ever manage to breed successfully.

Scientists already knew that like others across Europe, the Kielder vole population now varies less than it did until the 1990s. They suspected this would affect predators, but this study is the first conclusive evidence. It shows environmental change’s impact is cascading through ecosystems, affecting first herbivores and then the predators that eat them.

‘The decline is slow, and would be hard to detect simply by monitoring the number of adult owls. But the researchers’ population model suggests its ultimate results will be disastrous. ‘The owl population is ageing, and unless regular vole outbreaks return they eventually will die out – although that could be decades away,’ says Professor Xavier Lambin of the University of Aberdeen, senior author of the paper, published in *Global Change Biology*.

‘Tawny owls are very long-lived animals so if you just look at the number of individuals the situation might look reassuringly stable, but if you have more deaths than births there is only one possible outcome in the long term.’

**Owls in trouble in a changing world**

**Building evolution-proof drugs**
Getting ready for the next big one

Is one of the world’s great cities due to be struck by a serious earthquake? Ekbal Hussain describes how scientists are working to make sure Istanbul is prepared for the dangers that may be on the way.

Straddling the European and Asian borders, Istanbul is an ancient and beautiful city. Once known as Constantinople, it has been at the centre of major empires including the Roman, Byzantine, Latin and Ottoman. This great city is inundated with rich culture and history, and with nearly 14 million inhabitants it is also one of the largest cities in the world.

But this thriving metropolis sits on the edge of one of the fastest moving faults in the world: the North Anatolian Fault. This is a system of large fractures within the Earth on which energy, from the motion of the tectonic plates, is stored and released in earthquakes.

The North Anatolian Fault is roughly 1300km long, running along the entire length of northern Turkey from the Aegean Sea in the west to Lake Van in the east. It slips such that central and southern Turkey are moving west relative to northern Turkey at speeds of 20-30mm a year. It is the most active and destructive earthquake-prone fault system in Turkey.

It has been known for a while now that earthquakes on the fault tend to follow a regular sequence. That is, an earthquake will often occur on the section of the fault...
adjacent to the last rupture. Starting with the 1939 magnitude 7.9 Erzincan earthquake and culminating in the 1999 magnitude 7.4 and 7.2 earthquakes, there have been 12 events with magnitudes greater than 6.4 that together have ruptured almost the entire length of the fault.

The map shows this westward progression of seismic activity. The 1999 Izmit (magnitude 7.4) and Duzce (magnitude 7.2) earthquakes killed about 18,000 people, mostly in the city of Izmit. These events occurred less than 100km east of Istanbul, leading some researchers to predict the next quake will strike Istanbul itself.

Seismologists calculate the chance of an earthquake greater than magnitude 7 occurring near Istanbul in the next 30 years at somewhere between 35 and 70 per cent. And with almost a million people moving to the metropolis every year it is no surprise that Istanbul is a major candidate for the so called ‘million-death quake.’

We need to improve our ability to forecast such quakes by creating realistic models of the fault’s behaviour; and to do this we need to know more about the fault itself.

The NERC-funded FaultLab project based at the University of Leeds is helping address these problems, with support from the University’s Climate and Geohazard Services group. The investigators use data from a multitude of sources including satellite radar and geological observations, as well as data from the densest network of seismic stations ever deployed across a fault.

The project scientists aim to use the seismic data to investigate the deep structure of the fault and to see if there are differences in the crust either side of the fracture. The geologists will be looking at an old fault zone to probe the microscopic structure of minerals inside these large fracture zones. Together, these observations will enable us to better understand what the fault is doing deep in the ground and how this has affected the crust adjacent to it. The geodesy group (earth observation scientists) will use satellite radar to make accurate maps of how the ground surface is moving and relate that to the amount of energy being stored on the fault. Finally, the modelling team will link these observations together to produce an accurate picture of the behaviour of the fault. These results can then feed into models to make a more realistic forecast of the hazard Istanbul faces.

Earthquakes don’t kill people, buildings do.

A resilient city
Professor Nicholas Ambraseys, a leading expert in the field, famously said: ‘Earthquakes don’t kill people, buildings do.’

We technically don’t need to know when the earthquake will occur to save lives. Death and injury can be prevented through simple engineering works to reinforce vulnerable buildings and by ensuring new structures are built to earthquake-resilient standards. It’s estimated to cost only 10 per cent more to build a house that is earthquake resistant compared to one that isn’t.

The Turkish government has not been idle. The new Sabiha Gökçen International Airport terminal, which opened in October 2009, is designed to withstand shaking from a magnitude 8 earthquake and, importantly, keep working afterwards – this will be an important entry point for foreign aid after a disaster.

The Marmaray rail tunnel, opened in October 2013, runs beneath the Bosphorus Straits and links the European and Asian sides of the country. The rail tunnel was built to withstand a magnitude 9 earthquake.

In May 2012 a new Urban Transformation Law was passed, stating that all buildings that do not meet current earthquake hazard criteria will be demolished. This means nearly 6.5 million buildings throughout Turkey could be demolished over the next two decades, and will pave the way for more resilient cities.

Ambitions on this scale need strong governance and management, but they also need good science – to help the Turkish government prioritise its engineering projects and work on effective evacuation and mitigation plans. The results from the FaultLab project will help develop and refine their forecast models, so those plans can be put in action the moment there’s a sign that a deadly earthquake is imminent.

Ekbal Hussain is a PhD student in the School of Earth and Environment at the University of Leeds.
To find out more, see www.see.leeds.ac.uk/faultlab.
Email: eeehu@leeds.ac.uk
Data crunching in space

Satellite data will be vital as we try to protect a warming Arctic and make responsible use of the opportunities melting ice creates. But the sheer amount of it can create problems. Mick Johnson explains how new technology can help by doing more of the heavy lifting on board the satellite before the data is transmitted to the ground.

Scientific articles and news reports have highlighted the progressive shrinkage of the Arctic ice cap during the summer, as the annual mean extent of ice continues to fall steadily due to warming conditions in the region.

Since 1979, when we began to make continuous space-based observations, it has fallen by about 4 per cent per decade, reaching a record low in 2012. The minimum ice extent in 2012 was reduced to just 3.41 million km$^2$. Although the minimum extent of the ice cap was 50 per cent higher in 2013, it is expected that larger areas of the Arctic could be navigable during the summer from now on.

Commercial exploitation of the region is also growing, with rapid increases in oil and gas exploration, fishing, and new shipping routes under way. This raises major challenges; we need to monitor and protect this pristine area, while enabling exploitation to take place in a sustainable way. As well as monitoring sea ice to track the changing climate, it will also be essential to monitor shipping to observe both fishing and traffic, detect natural and man-made oil slicks, identify icebergs, and support navigation in the sea ice.

To achieve this over such huge areas, scientists use a type of satellite instrument known as Synthetic Aperture Radar (SAR). This uses complex data processing to obtain detailed images of sea ice and the sea surface. These provide large amounts of information about currents, the size of waves and the interaction between sea and atmosphere. It can even measure sea-ice thickness and detect small cracks in the ice, known as leads, which lets us route ships through ice-covered regions.

These and other applications such as offshore engineering and surveillance for disaster monitoring would benefit from the generation and dissemination of SAR products in real time. The problem is that the data processing needed to produce SAR images currently happens on the ground, creating delays of several hours or more in obtaining the images. Bandwidth limitations in data transmission from the SAR spacecraft to Earth add a further delay.

All this means the images arrive far too late to be useful for real-time applications.

To address this problem, Astrium and BAE Systems Advanced Technology Centre have been working together on a new initiative, funded by the Centre for Earth Observation Instrumentation (CEOI), to investigate the feasibility of generating SAR images in real time on-board the spacecraft.

The space-borne SAR sensor captures the raw radar data of radio waves bouncing back from the Earth’s surface (Level 0). The data then passes through a focusing algorithm to generate the radar images (Level 1). The image data are subsequently made available to...
Data crunching in space for the wider user community for higher-level processing to generate maps of geophysical features of interest, for example digital elevation maps and ice-flow maps.

In all space-borne SAR systems to date, the role of the equipment in space ends with capturing the Level 0 data. This is stored in the spacecraft’s memory and periodically transmitted to the ground for further processing.

By processing the data on-board, the Level 1 product, consisting of detected images and additional data necessary for subsequent processing, can be downloaded for immediate use. We can also reduce the amount of data that has to be transmitted considerably by smoothing the Level 1 images on board – this reduces their spatial resolution and also reduces the noise content in the data. This reduction in the volume of data removes a significant constraint in current systems, which are limited by the bandwidth of the downlink transmission system.

SAR image processing is very computationally intensive, requiring significantly more processing power than is available from general purpose computers that can be used in space, and requires special purpose hardware, either Application Specific Integrated Circuits (ASIC) or Field Programmable Gate Arrays (FPGA).

ASICs are powerful, but can only perform a single task. By contrast, using FPGA technology means we can reprogram devices in flight – in much the same way as we can reprogram software running on a general purpose computer, except that here we are changing the hardware itself. This opens up the possibility of reconfiguring the satellite’s hardware throughout its mission – we could even change it every orbit. For example we could periodically switch the hardware between data-capture and data-processing modes to allow it to make the most efficient use of the resources available.

In theory these changes could be made in software running on normal computers, but general-purpose computers that can be used in space are so slow that in practice this would be impossible. FGPAs offer the solution – like ASICs they are fast enough to handle the large amount of data the satellite’s instruments are generating, but we can also rewire them on the fly to do different jobs.

This work on SAR is just one example of a general trend towards processing more raw data on-board satellites. This is in response to the increasing resolution of modern sensors of all types, which means that in many cases it is simply impractical to store and forward the raw data to the ground. There is just too much of it – we need to reduce the amount of data before transmission, without reducing its usefulness.

In the CEOI work, Astrium has addressed the problem of mapping SAR-focusing algorithms into forms suitable for implementation in space-qualified FPGA hardware, and BAE Systems has provided expertise in SAR imagery and helped assess the quality of test images produced in simulations of the space-based processing.

CEOI is funding a wide range of innovative new instruments that measure our weather, our atmosphere, the icecaps, and many other aspects of the natural environment. Many, like these new on-board data-processing techniques, are finding fascinating new applications which can support us in our everyday activities. Whether we like it or not, our environment is changing; technologies like these will play a vital role in helping us minimise the threats and take advantage of the opportunities that change creates.

**Stage 3: the final processed image.**

Professor Mick Johnson is director of the Centre for Earth Observation Instrumentation. Email: mick.johnson@astrium.eads.net.

For more information about this technology and others, visit [www.ceoi.ac.uk](http://www.ceoi.ac.uk)
Space suit fitted: check. Helmet secured: check. Radio transmitter attached: check. Air supply pack turned on: check. Time to go into the airlock! While the simulated depressurisation of the airlock is ending, my fellow crewmember and I finish making our plans for the EVA – extra vehicular activity. I look through the porthole eagerly, in anticipation of stepping out onto the Martian terrain. It’s another sunny day on Mars, even though the temperature is still below zero. It’s a good thing our suits are thick enough to protect us against the cold, but that makes them very heavy: along with the air-supply pack they weigh 15kg.

As I walk over the rolling, red sandy hills of the stunning Martian landscape, I look back at the Mars Desert Research Station (MDRS). It is an analogue (simulation) laboratory – a copy of a planned NASA surface base on Mars – built by the non-profit Mars Society, which works closely with NASA and other international space agencies. The station is in the high, cold Utah desert, USA, where the environmental conditions, geological features and biological attributes are a good approximation of what we know about those on Mars. It was designed to help people learn about the challenges of living and working on Mars. The Red Planet is considered to be the nearest planet with the resources for humanity to inhabit and then to use as a stepping stone for expansion further into the universe.

I am one of several scientists selected to take part in a total immersion simulation for over two weeks. This means we spend every minute of every day facing the physical and social challenges of life as we would experience it on Mars.

We are here as analogue astronauts, subjected to psychological, nutritional and scientific studies designed by researchers from around the world. These include living with limited amounts of electricity, oxygen, water and dehydrated powder-like astronaut’s food. Crews for simulations are selected to include specialists in different fields of research that would be necessary for the exploration of Mars. Our crew commander is an aerospace engineer; we have a medical officer; two crew engineers, each specialising in a different aspect of space technology equipment testing; two crew scientists: a geochemist and myself – an astrobiologist and geologist. We also have a film-maker and even a humanoid robot, which we are testing out as a potential crew-member for real Mars missions.

We arrived at MDRS on 18 January 2014 and spent every moment of the simulation in total isolation from our terrestrial lives. The facility became our new home. It is made up of a habitat module nick-named the Hab, a greenhouse called the GreenHab and an observatory. The Hab is a two-storey cylinder-shaped building made to fit atop a heavy-lift space-launch vehicle. It’s only eight metres in diameter, creating a very

Mission to ‘Mars’

Some scientists may dream of the chance to pursue their research on another planet. That opportunity isn’t a reality just yet, but PhD student Michaela Musilova got the next best thing – a simulated mission to Mars.
confined living and working environment. The common room, on the top floor, also serves as dining room, workstation, kitchen and exercise area. The lower level contains the airlock, laboratories, bathroom and toilet, all crammed into a space the size of my living room. As a consequence, you are almost always within eyeshot and earshot of at least one other person, so, it was really important that the crew could work as a team and get along for a prolonged period despite the lack of privacy.

Each of us has our own scientific experiments to conduct, which involve lab and/or field work in the simulated Martian environment. They include field-testing NASA hardware that extracts hydrogen and oxygen from soil, a technology that could potentially produce breathable air, drinkable water and rocket fuel for a return journey to Earth. If it works, this equipment would dramatically reduce the weight and cost of future space missions.

Our team also carried out simulated surgeries, via Skype, with several research groups around the world including the French/Italian Concordia base in Antarctica. The goal of these ‘tele-surgeries’ was to understand the difficulties faced when medical experts have to direct non-experts in an emergency, with restricted and delayed telecommunications – a situation astronauts travelling to Mars are likely to find themselves in.

One of the engineering projects is on prototype spacesuit glove technology. Our gloves have to be thick but these prototypes are nevertheless designed to feed information to the user’s fingertips about the texture and temperature of what they are holding, giving the astronaut a better awareness of the samples they are handling and the environment around them.

Another engineering project is testing rover cameras and a 3D mapping system similar to the one that will be on the ExoMars rover (scheduled for launch to Mars in 2018).

My own research is on extremophiles: organisms that live in physically or chemically extreme environments and are therefore significant for understanding what kind of life might exist on other planets and to help us develop the technologies to search for it. At MDRS, I am investigating two important questions: whether terrestrial microbes can survive in Mars-like conditions and thus whether there could be similar life on Mars; and whether these extremophiles could be used for terraforming Mars – recreating Earth-like conditions. Without terraforming or some other way of creating conditions for agriculture on Mars we could never properly settle on the Red Planet.

Today, I set out to collect more extremophiles for my experiments in the Hab (and for further analysis during my PhD). I love doing this simulated Martian fieldwork. Regardless of how hard it is to move around in my heavy spacesuit, breathing artificial air in my fishbowl helmet, I am completely absorbed in my role as an analogue astronaut. Walking towards the red Martian hills on the horizon I feel, more than ever, that I am on the path towards my childhood dream of going into space for real.

Michaela Musilova is a PhD student at Bristol University.
Email: m.musilova@bristol.ac.uk, @Michaela_MDRS.
She received a Royal Geographical Society postgraduate award for her research at MDRS.
For more information about Michaela and her mission to Mars visit www.bristol.ac.uk/geography/people/michaela-musilova/index.html and http://marscrew134.org/why-mars/
Insect-transmitted disease is a tragic fact of life for many in tropical and subtropical areas, killing people and livestock and causing immense suffering and economic loss. Now climate change and ever-more-intricate transport networks mean the threat is spreading. Warmer, wetter weather creates new habitats for the vector insects that transmit infections.

A recent midge-borne Bluetongue outbreak cost France alone an estimated €1 billion, and people have already died from emerging diseases in southern Europe. Mosquitoes previously confined to the tropics are appearing in new areas; members of the tough Aedes genus are now firmly established in Italy and have been found as far north as the Netherlands, hitchhiking in cargoes of old tyres and the popular houseplant lucky bamboo.

Some experts even fear that malaria – a deadly threat that’s been almost unknown in Europe for generations – could be on the verge of returning, spread by the Anopheles mosquito genus. Less familiar diseases are appearing too; authorities have already found insects that carry viruses like chikungunya and yellow fever in the wild.

**Mycology against malaria**

Insect-borne infections take an appalling toll across much of the world, and they’re turning up in new places. Tom Marshall finds out how fungi could help us fight back.

Insect-transmitted disease is a tragic fact of life for many in tropical and subtropical areas, killing people and livestock and causing immense suffering and economic loss. Now climate change and ever-more-intricate transport networks mean the threat is spreading. Warmer, wetter weather creates new habitats for the vector insects that transmit infections.

A recent midge-borne Bluetongue outbreak cost France alone an estimated €1 billion, and people have already died from emerging diseases in southern Europe. Mosquitoes previously confined to the tropics are appearing in new areas; members of the tough Aedes genus are now firmly established in Italy and have been found as far north as the Netherlands, hitchhiking in cargoes of old tyres and the popular houseplant lucky bamboo.

Some experts even fear that malaria – a deadly threat that’s been almost unknown in Europe for generations – could be on the verge of returning, spread by the Anopheles mosquito genus. Less familiar diseases are appearing too; authorities have already found insects that carry viruses like chikungunya and yellow fever in the wild.

**Threats on the horizon**

The European Centre for Disease Prevention and Control monitors the fringes of Europe to get early warning of new dangers before they arrive in force, but it’s likely some will get through. Professor Tariq Butt of Swansea University is involved with several projects aimed at developing new techniques that will help in the fight against insect-borne diseases both in new territories and in the regions they’ve troubled for millennia.

He’s an expert on entomopathogenic (insect-killing) fungi – particularly Metarhizium anisopliae, or green muscardine fungus. This is deadly to many arthropods, and has already been turned into an innovative biological pesticide that kills crop pests without harming beneficial insect species.

Butt’s attention has now turned to insects and other arthropods that carry disease, and he thinks Metarhizium can help fight continent-spanning scourges like malaria and dengue as well as rarer infections like Crimean-Congo hemorrhagic fever.

Until recently efforts to control insect-borne disease have relied on chemical insecticides, but these have major drawbacks. They’re costly, they can pose serious health risks if used incorrectly (the Stockholm Convention on Persistent Organic Pollutants says ten of the 12 most dangerous and persistent chemicals are pesticides) and they kill bugs indiscriminately – not just disease carriers, but predators that eat them, pollinators that are vital for local crops and anything else in the area.

Target species eventually develop resistance to chemical treatments too, so ever-greater quantities must be applied. Because of all this, policy-makers are imposing increasingly stringent controls that mean many formerly-popular pesticides are no longer on the market at all.

Known strains of Metarhizium are deadly to vectors including...
mosquitoes, midges and ticks. The fungus kills adults and juveniles alike, but ignores non-target species and doesn’t pollute the environment. It’s harmless to humans, and target insects can’t develop immunity. Butt is working with projects investigating its potential all over Africa, Turkey and the Middle East, collaborating with organisations from NGOs and pest-control companies to the US military.

_Metarhizium_ won’t solve all our insect problems alone. But it’s a promising tool, taking its place as part of an integrated control strategy alongside methods like pheromone lures, mass trapping and releasing sterile insects.

**Going underground**

One promising initiative targets sand flies, which spread Leishmaniasis, a widespread disease that causes painful sores, fever and serious organ damage. It’s been of particular concern to the US military since it started appearing in personnel who’d been posted to Iraq and Afghanistan.

The initiative has brought Butt’s group together with the US Naval Medical Research Unit No. 3 (NAMRU 3) in Cairo, a major part of whose mission is to research health threats to both US personnel posted abroad and local people. Butt has worked closely with Dr Alia Zayed, deputy head of NAMRU 3’s Vector Biology Program and a professor at Cairo University with long experience of biological insect control.

Until now, spraying has been the usual measure against sand flies, but this has many disadvantages. Its cost is a particular problem for the remote rural communities that suffer most from Leishmaniasis, and it causes widespread ecological damage. It also reaches only adult flies on the wing; it can’t touch juveniles, which usually live underground in rodent burrows and livestock pens. The researchers decided finding a way to kill the young flies before they become dangerous would let them control the sand fly problem sustainably.

Butt’s laboratory isolated a fungal strain that kills the flies efficiently, and Zayed and her colleagues applied it together with another Egyptian strain to burrows and animal pens around trial villages in Ghana. ‘So far the results have been phenomenal,’ Zayed says; the fungus reduces the adult sand fly population by more than 85 per cent under controlled field conditions. The trials will be repeated in Ghana this year to confirm the results. If all goes to plan, and if the drop in sand fly numbers has the expected effect on local people’s risk of disease, it will be a huge step forwards.

Applying the fungus to sand flies’ breeding sites

First trial in Ghana – chief of village receiving instructions on applying the fungal material to sand fly breeding sites.

![Light micrograph of the parasitic fungus Metarhizium anisopliae](image)
sites in the soil will allow less of it to be used in a more focused way. Building resistance against the fungus isn’t a concern – its killing methods are the result of millennia of evolution, so they’re exquisitely deadly. And in most places it can be grown locally on cheap, widely-available materials, letting people set up their own pest-control cottage industries.

Extermination isn’t the goal – that would be prohibitively expensive and probably impossible. Zayed’s aim is more modest; simply to learn to control sand flies in built-up areas and around people’s houses by attacking what were previously safe underground refuges. ‘We can’t kill them all, but we can lower the population to reduce the risk that people nearby will be bitten by an infected fly,’ she explains.

**Pushing back malaria**

Perhaps the biggest target for efforts at insect-borne disease control is malaria, which killed some 660,000 people in 2010, 90 per cent of them in Africa. About half the world’s population is at risk of the disease. *Metarhizium* has huge promise here too. Zayed and Butt are working with US biocontrol firm Suterra, to develop new mosquito attractants and repellents; the company is sponsoring one of the PhD students working on the subject in Butt’s team.

The team hope the new compounds will be used to attract mosquitoes away from people’s homes and into traps or monitoring facilities. The US Army is also involved, providing funding and letting the researchers use its wind tunnels to test how attractants affect mosquitoes’ movements in different conditions. ‘The attractant could be pheromones or food, or anything else the target insect is attracted to,’ says Zayed. ‘It’s just like attracting ants with sugar.’

New repellents are another goal; chemically-treated mosquito nets are a vital weapon against the disease, and NGOs like the Gates Foundation have invested heavily. But it seems some of the benefits of this approach are fading. Mosquitoes adapt, for example appearing earlier in the evening before people retreat behind their nets, and seem to be developing resistance to widely-used repellents like Deet. Alternatives are urgently needed.

‘The days when we thought we could just cover the landscape in insecticide are long gone; we need a many-pronged approach,’ Butt says. ‘So we keep the mosquitoes away from people with repellents; we mask the body odours that attract them; we develop new lures and use them to bring the insects to places where we can easily kill them.’

He’s been working on trials across Africa, and some of *Metarhizium*’s capabilities surprised even him. Dealing efficiently with adult insects is par for the course, but for some reason the fungus can even kill mosquito larvae under water, and Butt was recently astonished to discover how. It doesn’t even need to use its standard methods of infiltrating and killing adult insects with its armour-piercing threads; instead, genetic analysis shows that the larvae are effectively stressed to death.

Their immune systems evolved to deal with an underwater environment, and have never encountered anything remotely like a soil-dwelling, insect-killing fungus. So the young mosquitoes’ own stress response kills them; just scatter the spores onto the water’s surface and larvae beneath eat them and start dying.

These discoveries suggest exciting new possibilities. The African rainy season turns the landscape into a mosquito’s paradise, full of ponds and puddles suitable for breeding. To deal with them by spraying you’d have to blanket the countryside in insecticide. But if you can attack the larvae under water, you can wait for the dry season, when the breeding grounds are far fewer and smaller, and dose them individually with fungal spores.

Butt’s plan is to clean out the mosquitoes from towns and create a buffer zone around to prevent re-infestation – mosquitoes can only fly a few miles, so treating water sources near a city should largely neutralise the threat to its inhabitants. ‘We’re not going to eradicate them – just suppress them to levels where they’re not dangerous to humans,’ Butt says. If we can reduce the mosquito population when it’s already small, during the dry season, then it won’t be able to expand again to such a dangerous extent when the rains arrive.

Trials of these fungal mosquito control methods have already taken place in countries including Turkey and Tanzania; more are scheduled for Ghana in 2014. Other collaborations are under way in places including Kenya and Brazil.

Butt emphasises that a problem as widespread as malaria in sub-Saharan Africa needs a whole range of methods – an approach known as Integrated Pest Management. He wants to develop new tools that health professionals can use as appropriate in different situations. ‘Rather than relying on a single approach, we need to aim for a more diverse and sustainable strategy that uses several different methods together,’ he says. ‘When it comes to disease control, there’s no silver bullet.’
In 2013, the British Ecological Society celebrated its 100th birthday and we decided to mark the occasion with a bang. The society’s mission is to advance ecology and make it count, so outreach and public engagement were main features of the centenary activities. We wanted to contribute something different and creative, taking ecology to a place where people wouldn’t normally expect to find it. So we joined the thousands willing to endure rain and mud for the acts on offer at Britain’s music festivals, and took to the road with Sex & Bugs & Rock ’n Roll.

The festival ‘roadies’ were active researchers, from PhD students to lecturers. We had a lot of fun thinking up novel and entertaining ways to present various aspects of ecology at our eye-catching tent. Our games and activities revealed the microbes on people’s festival clothes, introduced the strange world of mushroom aromas, and had people identifying animals by what they leave behind. In keeping with our wildflower meadow theme we ran guided bug-hunts around the festival site and had a live bumblebee colony on display.

People enjoyed all of these but to our surprise we roadies were often the main attraction. We were asked a myriad of questions about our research and broader topics such as wildlife-friendly gardens, strange species spotted on Sunday strolls and beneficial microbes. At each festival, our big blue tent became a hive of conversation and debate.

We’d hoped Sex & Bugs would be a hit, but we didn’t anticipate just how popular it would turn out to be. Many of our visitors had started out with an entirely different plan for their day but were delighted by the unexpected opportunity to explore their personal interest in ecology. Engaging the public with science is nothing new – museums and science fairs are as busy as ever – but Sex & Bugs was an ambitious attempt to break the mould and take science to the public. This approach can broaden the audience for science by providing a less formal venue than a classroom or museum, where people can ask questions or tell their own stories without feeling intimidated. Evidently the setting made us seem very approachable as our visitors had no hesitation in coming to us with questions or just to share our own fascination with our subject.

The initiative has been an overwhelming success on both sides: visitors could explore ecology on their own terms, and the researchers learned new ways of communicating and got a different perspective on their work. The support and enthusiasm from the public and scientific community alike has been overwhelming.

Last year, we visited three music festivals, talked to over 5000 visitors, and received more than 10,000 visits to our blog, and the ‘roadies’ will be busy again this summer – jumping from lab bench to muddy field. We’re pleased that the success of Sex & Bugs is encouraging other researchers to get out there too. Scientists need to take public opinion into account to ensure that their research benefits wider society; in our experience the best way to achieve this is to take science to the people, instead of expecting them to come to us.

Emma Sayer and Frazer Bird were on the original organising team for ‘Sex & Bugs’, when not touring festivals, Frazer is a PhD student in palaeoecology at the Open University and Emma is a lecturer in ecology at Lancaster University.

Email: frazer.bird@open.ac.uk

You can find out where Sex & Bugs & Rock ’n Roll will be this summer by visiting www.besfest.org or following the roadies on Twitter @BESRoadies
A debate about the historical stability of the Antarctic ice sheet has raged for decades, splitting the community of scientists studying the ancient climate along increasingly partisan lines. It concerns the evolution of the ice sheet’s thermal condition – that is, how fixed it is to its bed, how stable it is, and how it has contributed to global sea levels through geological time.

Our efforts to settle these questions have included several expensive offshore and onshore drilling campaigns. Yet until recently, no resolution has been in sight. Now the definitive answer has come from an unexpected direction – from studies of Antarctic volcanoes that have erupted under the ice cap.

It may seem counterintuitive that volcanic hot spots can tell us about past ice sheets, but studying them has revealed for the first time that the ancient Antarctic comprised a mosaic or patchwork of warm and wet ice alongside areas of cold ice frozen to its bed. This is called a polythermal ice sheet and the result, just published, represents a radical change in our thinking.

The old view was that the ice sheet has existed over time in one of two major thermal states: it was either warm, wet and mobile or cold, stable and frozen to its bed. This is called a polythermal ice sheet and the result, just published, represents a radical change in our thinking.

The new view is that the ice sheet has existed over time in one of two major thermal states: it was either warm, wet and mobile or cold, stable and frozen to its bed. This is called a polythermal ice sheet and the result, just published, represents a radical change in our thinking.

The old view was that the ice sheet has existed over time in one of two major thermal states: it was either warm, wet and mobile or cold, stable and frozen to its bed. This is called a polythermal ice sheet and the result, just published, represents a radical change in our thinking.

The old view was that the ice sheet has existed over time in one of two major thermal states: it was either warm, wet and mobile or cold, stable and frozen to its bed. This is called a polythermal ice sheet and the result, just published, represents a radical change in our thinking.
and their environmental record. Most of them are very remote and hard to visit, but the rewards are great. The volcanoes are exceptionally well exposed in cliff sections nearly 1000m high and extending many kilometres.

Using helicopters and often working from the sea ice at their foot, we accessed the volcanoes and obtained an unrivalled and hitherto completely unknown record of Antarctic ice, its thickness and thermal state.

Unlike the sediments of the Sirius Group, volcanic rocks can be easily and precisely dated. This is because they contain radioactive minerals, whose ‘radioactive clock’ began ticking from the moment they erupted and quickly cooled. Sedimentary rocks contain mixtures of radioactive minerals indiscriminately eroded from a variety of sources, all of which are older than the time when the sediment was deposited, so we cannot date them in the same way. We hoped our study of the volcanic rocks would let us verify the step change in the ice sheet’s thermal state, and obtain the first reliable and exact age for that change.

The results were a revelation. Unexpectedly, we began discovering evidence that the thermal state switched back and forth between warm and cold conditions and it also varied from place to place. In other words, ancient Antarctica was polythermal – a patchwork of thermal states. We were stunned. The paradigm that had existed for many decades had to change.

In some respects the result was less surprising than it initially seemed. After discovering many subglacial lakes in Antarctica, we now know that the modern ice sheet is polythermal, including in East Antarctica. But this is the first clear sign that the ice sheet has probably been polythermal throughout its history, or at least for the last 12 million years.

Our results are just in, and they are still being assessed. Modelling the future flow of an ice sheet with such variable thermal states may be extremely difficult. Although we now know that the ice was polythermal, it will be some time before we have a detailed idea of when, where and how the changes happened. In the light of our discoveries from the volcanic studies, recreating a poorly-defined patchwork ice sheet that is slippery and fast-moving in one area while cold and slow in others is mathematically very complicated.

However, our studies have clearly demonstrated that volcanoes are a major repository for environmental information that was largely ignored until recent years. That is a mistake we will not make again – we will be back in Antarctica in 2014 further evaluating past conditions of the Antarctic ice sheet.

John L Smellie is a professor in the Department of Geology at the University of Leicester, specialising in glaciovolcanism.

Email: jls55@le.ac.uk

Geologists traversing a volcanic ridge in Antarctica with active ice-clad Mount Erebus volcano (3800m) in the background.

Spectacular cliff section hundreds of metres high at Cape Washington, constructed of multiple lava sequences formed during subglacial eruptions 2.8 million years ago.
You may have seen underwater video of towering pillars of deep-sea rock, billowing out super-hot black water, covered in strange white crabs or bright red tubeworms in programmes like The Blue Planet. These are hydrothermal vents, often considered among the greatest scientific discoveries in the natural world.

But impressive as these hydrothermal chimney ecosystems are, they are not alone in the deep sea. We know far less about what happens when hot water from deep within the Earth flows through muddy seabed in so-called ‘diffuse-flow’ vents. Here, it mixes with cold sea water beneath the seabed, which means it doesn’t form the iconic chimneys, because the water cools down too slowly – but also that these ecosystems host completely different animals.

The important distinction between chimneys and diffuse-flow vents is how different they are from the rest of the deep-sea floor. Away from mid-ocean ridges and trenches, most of the deep seabed is an endless plain of thick, soft mud. Most seabed animals are adapted to this environment, endlessly hoovering up food particles that sink down from the surface.

In contrast, hydrothermal chimneys are hard and jagged, so it’s difficult for animals adapted to the mud to live there; likewise, animals adapted to the chimneys can’t live elsewhere. Diffuse-flow vents and cold seeps are much more like normal deep-sea conditions. They still host specialised animals, like giant deep-sea clams, but it’s much easier for other deep-sea creatures to take advantage of the extra food being produced. This has a couple of interesting effects. Firstly, it promotes diversity and abundance of life; secondly, it means the animals are much more active here than in normal deep-sea sediments – and that has implications for our entire climate.

In most places on Earth, all the energy needed for life comes from the Sun, which plants use to create sugar through photosynthesis. But at deep-sea vents, the water is laden with special compounds, which bacteria can use to fix energy with no need for sunlight – a process known as chemosynthesis. Energy is supplied by unlocking stored energy in the chemical bonds of these compounds, such as hydrogen sulphide, or methane.

Temperatures at diffuse-flow vents are around 40-50°C above normal, lower than at chimneys (which can reach 400°C), but not all chemosynthetic environments are hot. Chemosynthesis can also occur at completely normal deep-sea temperatures, in regions where hydrocarbons like methane exist beneath the seabed – so-called ‘cold seeps’. Like diffuse-flow vents, these seeps are physically not so different from the normal deep-sea floor, and they are interesting for the same reasons.

Turning carbon into rock
So what does this mean for the climate? One of the most important ways that excess carbon dioxide is removed from the atmosphere is by plants in the surface oceans, some of which sinks to the sea floor. When it gets there, the animals that live in the seabed eat it, and in doing so mix up the sediment and increase how quickly the carbon gets locked down in the mud where it will eventually become rocks like chalk or limestone.

Diffuse-flow vents and cold seeps attract lots of animals because there is more food there. This means the sediment potentially gets mixed much faster, so carbon could be removed from the oceans more quickly. Until the sediment is buried and on its way to forming rock, very turbulent waters called benthic storms can stir it up again and send carbon back towards the surface. The Earth’s crust is the ultimate long-term repository of carbon and to understand our climate, we need to know how carbon gets there from the atmosphere.

We have an idea of how this might work, but no real sense of how important these
ecosystems are globally. Among the big questions we are trying to answer are how fast carbon is buried, and how much of it came originally from the atmosphere – some of this will have come from burning fossil fuels and some will have been produced by the local bacteria. If we can measure how quickly carbon from the atmosphere is buried, we will get a better impression of how the oceans might change in the future.

So, how do we answer these questions? First, you need a ship, and NERC sent one out to the Southern Ocean with a team of UK biologists and geochemists in 2011 to collect samples from some of these ecosystems.

The next stage is to look at the animals in these samples and work out exactly what they are. Often, the difference between two species is very small and, quite possibly, unknown to science altogether, but this is a vital step towards understanding the diversity of animals present. We inevitably identify new species; this involves sequencing their DNA and describing their physical form in detail. This is important work for conservation – we can’t protect species from extinction until we have discovered them and understand their distribution.

Most of the species I’ve found are small, segmented worms called polychaetes, not unlike the earthworms in your garden, but there are also a lot of mussels and crustaceans. The animals I am interested in are very small, typically not more than a few millimetres long, but there are so many of them that they can make a big difference to the seabed.

Once we have identified and counted all the specimens, we can begin constructing a food web. To do this, we use the elements carbon, nitrogen and sulphur, which naturally take various forms with different atomic weights, called isotopes. The isotopes of an element present in an animal’s body form a unique signature based on its diet, letting us pinpoint its position in the food web. Using the data we get from measuring their isotopic signatures, we can model how they interact, both with each other and with their physical environment, for instance how carbon moves through the ecosystem.

Modelling carbon cycling in soft-sediment chemosynthetic ecosystems is an entirely new facet of marine research. Scientists worldwide are only beginning to get this kind of perspective on the deep sea and we still don’t know what we are going to find. Part of what makes the project so interesting is that it involves a wide spectrum of ecological research – from the possibility of discovering brand new species, through finding out how these animals interact with their environment to discovering what this all means for big-picture issues like conservation and climate change. What’s inspiring is the chance to explore an aspect of the world for the first time and find out things that no one knew before.

James Bell is a PhD student at the University of Leeds and Natural History Museum. E-mail: gbjb@leeds.ac.uk. Twitter: @james_chesso

Chemosynthetic Ecosystem Science
www.coml.org/projects/biography-deep-water-chemosynthetic-ecosystems-chess
When we think about marine life the big stuff usually springs to mind: fish, sharks and whales. But these iconic creatures are far outnumbered by their much smaller, much older, distant relatives. Christine Campbell gives us a glimpse into the world of microbes and the many things they can tell us.

They may be invisible to the naked eye, but microbes make up a surprising 90 per cent of ocean life and are amongst the oldest forms of life on Earth.

Blue-green algae (cyanobacteria) are well known – mostly as a nuisance – but not many people realise quite how ancient these organisms are, with examples dating back around 3.4 billion years. With such a long history it should be no surprise that microbes appear on nearly every branch of the tree of life. They flourish in a huge range of environments, from shallow seas to hydrothermal vents and the frozen poles. Marine microbes form the base of the ocean food chain, drive global nutrient cycles and have a major influence on our climate.

Microbes are staggeringly diverse. They include protozoans, unicellular and chain-forming colonial algae and cyanobacteria, and these groups themselves contain thousands of species, each with unique characteristics. Some cyanobacteria can tolerate extremely low oxygen and light levels and are even resistant to UV radiation, which enables them to thrive in areas inhospitable to most other life-forms such as hot springs.

Despite their unrivalled abundance, their size and capacity to inhabit extreme environments makes microbes rather difficult to study. It is time-consuming
and expensive to collect samples and not everyone who wants to study them has the time or resources to collect, isolate or cultivate microbes for themselves.

So specialist labs called culture collections play host to different strains of microbes collected on research cruises and field trips, creating just the right conditions to keep them alive for future study. The Culture Collection of Algae and Protozoa (CCAP) lives at the Scottish Association for Marine Science in Oban. CCAP hosts around 3000 strains of algae, cyanobacteria and protozoa and is the most diverse collection of its kind in the world. It is in reality like a microscopic botanic gardens and zoo combined, but as a scientist you can take the plants or animals home, or at least to your own lab!

Some of CCAP’s microbe strains have been kept alive for over a century. The collection was started by Professor E G Pringsheim, a German academic who came to England in 1938. Pringsheim isolated more than 150 different strains, many in light regimes. Almost all the strains have to be transferred regularly (on average monthly) into fresh medium to keep them alive – a delicate and laborious process. In some cases strains are maintained through cryopreservation, which involves keeping them in suspended animation in liquid nitrogen at -196ºC where they can last without deteriorating for hundreds of years.

We go to so much trouble because these ancient and diverse organisms have so much to teach us.

The fact that some strains can only tolerate quite specific conditions makes them useful biomarkers – by matching ‘fossil chemicals’ in sedimentary rocks with similar chemicals found in cultures held in CCAP today we can get a picture of ancient climates and environmental change. Microbes have a major influence on the environment; they are responsible for 50 per cent of global oxygen evolution and have even been explored as tools for bioengineering our environment to reverse climate change.

We go to so much trouble because these ancient and diverse organisms have so much to teach us.

Looking after these tiny pets is no easy task. Most of the strains live in test tubes in a specially formulated water-based solution or on the solid growth medium called agar. As most strains will only tolerate certain environmental conditions, the test tubes are kept in different rooms each maintained at a constant temperature under standardised environmental conditions, the test tubes are

Their unique biological properties also mean some CCAP microbes have a much more direct influence on our everyday lives. Microbiologists and biotechnologists around the world study the chemical compounds behind the microbes’ exceptional properties to see if they can isolate and mimic them for the benefit of we humans: a UV-resistant compound, for example, could be invaluable in our sun creams. Marine algae have been found to contain a number of compounds which are now ingredients in many everyday products. The pigment that gives blue-green algae *Spirulina* its colour and is the source of the pink colour of the lesser flamingo – beta-carotene – is used as a food colouring. Other compounds from algae have been found to be useful in a wide range of pharmaceutical, cosmetic and nutritional products.

For companies striving to create more ‘natural’ products in particular, the marine microbial world is an important and relatively untapped resource. CCAP supplies many strains to commercial companies on the hunt for natural ingredients, new sources of lipids for human or animal foods and bioactives with the potential to produce new antibiotics or compounds with anti-cancer activity. In addition, it acts as an official international depository authority for patent organisms, maintaining patent strains for a fee and supplying them only to the depositor or those who have paid to access the strain.

The potential for marine products extends far beyond everyday consumer products or bioactives. Marine algae are being researched as a source of oil for biofuels and other petrochemical replacements. Initial studies have shown that some species of marine microalgae could provide up to ten times more oil per hectare of land than any terrestrial crops currently being used, without compromising valuable freshwater resources.

Microbes can also be a really engaging way to enthuse people about science. *Pyrocystis lunula* is a bioluminescent dinoflagellate – it glows in the dark and is the source of the glittering light you sometimes see in the sea at night. CCAP has supplied samples to schools and to TV companies making children’s programmes, and the pretty microbe has been the inspiration for and star of several art installations.

Supporting everything from crucial climate change research to the natural products revolution, the benefits of collections like CCAP are as diverse as their tiny house-guests.

Christine Campbell is marine curator of CCAP.
Email: christine.campbell@sams.ac.uk
Taking the environment’s pulse

Long-term observation of our ecosystems is critical for us to understand environmental change. Andy Sier looks back on the contribution of 20 years of observation and research by the Environmental Change Network.
The only thing constant in life is change,’ wrote French author François de la Rochefoucauld. This is certainly true of the environment, which is in a continual state of flux. But that change may be so slow as to be almost undetectable, so we need long-term monitoring and research programmes to gather rigorous data on our ecosystems. This is exactly what the UK’s Environmental Change Network (ECN) has been doing for the last 20 years.

These data are a unique resource for understanding patterns and causes of environmental change. They support a wealth of environmental research and policy decisions in areas such as climate change adaptation, air and water quality and biodiversity loss.

ECN was established in 1992 in response to calls for more long-term, quantitative information about the state of the environment and how it was changing. Initially set up with 12 terrestrial sites, ranging from lowland farms and woodlands to upland moors and mountains, since 1994 we have also taken data from a network of lakes, rivers and streams.

At each site, scientists make a wide range of high frequency, closely located environmental measurements, using standard protocols that let us compare trends at different sites.

We manage all these data – as well as data from four other monitoring networks – in a central database containing millions of records. Since the earliest days of ECN, the data have been freely available for non-commercial use including research and teaching, with a helpful data portal that enables users to explore, and plot summary data or access datasets.

So what have we learned about how the environment has changed in the last two decades? Perhaps the most significant change has been a marked reduction in the deposition of sulphur compounds – so-called ‘acid rain’ – primarily because of changes in energy policy and greater international regulation of emissions from power stations. This is reflected in large reductions in sulphate concentrations in rainfall at ECN sites and corresponding reductions in the acidity of water in our soils, although so far we’ve not seen any clear responses in vegetation.

These aren’t just interesting observations – they have real-world impact through their contribution to policy and regulation. Our acid rain observations, for example, were used in the recent Defra-funded UK Review of Transboundary Air Pollution, which was led by NERC’s Centre for Ecology & Hydrology and informs the development of UK air quality strategies.

Defra has long used ECN data on populations of invertebrates like beetles, moths and butterflies as indicators of how ecosystems are responding to climate change. For example, we’ve seen large changes in the abundance of ground beetles at ECN sites, as reported previously in Planet Earth Online*. These changes may be linked to the climate but differ in strength and direction between habitats. So we’re doing more work to understand why species respond differently to environmental change, which could benefit local habitat management practices.

One of our sites, Moor House-Upper Teesdale, is a nature reserve in the Pennine hills of northern England. Large parts of it are upland blanket peatland which are important sources of drinking water in the UK. But the water is typically coloured brown by dissolved organic matter (DOM) from the peaty soils and this is a real headache for the water industry – drinking water must be chlorinated by law but chlorinating water with a high DOM concentration can produce potentially harmful bi-products such as trichloromethanes. So DOM has to be removed before chlorination, and this is expensive.

Working with colleagues at the Upland Waters Monitoring Network, we’ve seen DOM concentrations in upland streams across the UK double over the last few decades, leading to a substantial rise in water treatment costs. This has triggered great interest in the likely causes of change and whether the scale of the problem can be reduced by altering upland management practices such as heather burning or soil drainage. Researchers are turning to ECN soil and water data from peaty sites like Moor House, Glensaugh and Sourhope to help understand peatland processes, including the factors controlling DOM concentration – critical knowledge for developing appropriate strategies to protect water quality and human health.

Looking to the future

Although ECN’s 20-year datasets support a wide range of research, we need to be pragmatic. To continuously monitor environmental change at a single place in detail is a major commitment. If we had more sites, took more types of measurement, or made measurements more frequently, we would undoubtedly improve our understanding of these environments, but this is unrealistic in the present economic climate.

The answer is greater integration, and for ECN this means linking up more effectively with other environmental recording programmes, including amateur enthusiasts, citizen science initiatives and socio-ecological studies.

We are therefore looking for better ways to integrate with other national datasets and to share new measurement technologies. It is critical that we work together to develop shared tools so users can easily find, combine and use the data they need.

ECN has come a long way in the last two decades and is making significant contributions to our understanding of how and why our ecosystems are changing. Our challenge now is to ensure we get as much scientific benefit as possible from all this information in the decades to come.


Andy Sier is ECN’s science liaison officer.

Email: arjs@ceh.ac.uk.
ECN is coordinated by the NERC Centre for Ecology & Hydrology. It is supported by a consortium of partners responsible for site-based monitoring, research and analysis. For full details and to access data see www.ecn.ac.uk

Andy Sier, ECN science liaison officer.
That sinking feeling

February 2014 saw the appearance of at least three times more sinkholes in the UK than is normal for a whole year. Sue Nelson talks to experts from the British Geological Survey to find out what’s making these huge holes open up.
Sue Nelson: One five-metre hole on the M2 in Kent, another in a High Wycombe driveway, a seven-and-a-half-metre hole that caused three homes to be evacuated in Yorkshire, and 20 houses evacuated around a giant hole in Hemel Hempstead...

Principal geologist Tony Cooper and engineering geologist Vanessa Banks – I know sinkholes are holes in the ground but what’s the technical definition?

Tony Cooper: Strictly speaking a sinkhole is a natural phenomenon caused when rock dissolves underground and the surface above collapses. But a lot of collapses are due to mining and ancient workings – including so-called deneholes in the south of England. The result is the same and in places it is very difficult to tell the difference between a man-made sinkhole and a natural one.

Sue Nelson: So a denehole is one of these man-made holes?

Tony Cooper: A denehole is a shaft, usually dug to extract chalk to fertilise the ground in medieval times. They would dig through weathered rock to reach chalk that contained more minerals. Then that area would be enlarged and have more tunnels dug out from it. When they had finished they would just block the top of the shaft and cover it, often leaving no sign at the surface.

Sue Nelson: I gave a few examples of where these sinkholes have been occurring over the UK. Is there something that connects all these places?

Tony Cooper: There is a connection in that they are all areas of soluble rock. We’ve basically got four types of soluble rocks in the UK that give us sinkholes: chalk, limestone, gypsum, which is the raw material for plaster and dissolves very quickly – if you took a block the size of a large van and put it in a river it would dissolve in about 18 months — and salt.

Sue Nelson: What sort of research do you do here that helps you know which areas are more likely to have sinkholes?

Vanessa Banks: We are interested in how water moves into and through these soluble rocks, how its chemistry changes as it moves through the ground, and how it emerges from the ground as springs. We put a lot of effort into understanding these flow paths and one of our specialists does ‘dye tracing tests’.

Sue Nelson: So you put some dye in at the top end and see where it comes out to work out which route it has taken?

Vanessa Banks: Absolutely – either a dye or another inert substance that doesn’t affect water quality, But the water may take more than one pathway so we’re monitoring lots of springs.

Sue Nelson: The wettest January in centuries and a pretty soggy February sound like ingredients for a perfect storm for sinkholes.

Tony Cooper: Compared to the amount of people affected by storm damage or flooding, the number of people affected by sinkholes actually is very small. Even in parts of the country with lots of sinkholes you are more likely to suffer damage from other things. It’s just a more unusual sort of thing to happen and it is very drastic if it does happen under your house — but not that many houses are actually affected by them.

Sue Nelson: How do you reassure people who live above soluble rocks that a sinkhole isn’t going to appear in their back garden anytime soon?

Vanessa Banks: They have occurred in the past in response to prolonged rainfall, but it will very much depend on where the increases in storms and rainfall occur.

Sue Nelson: You’ve got all this research here and all this knowledge about the UK – I suspect the insurance and building industries would be very interested in the research you do?

Tony Cooper: Yes – we’ve actually looked at the whole country to see the distribution of the soluble rocks and the places that are more prone to dissolution and we’ve created a product called ‘Geosure’ for the insurance industry. It doesn’t really affect people’s insurance premiums but it gives the insurance business a handle on where their liabilities lie.

We also feed our research into the building industry and in certain places they do have to take account of the sinkhole situation. Some places have special planning routines in place, which involve detailed investigation and require appropriate mitigation measures to be put in place. The problem comes in actually interpreting the geology and whether mitigation measures are robust enough – so there is some discussion going on about what are suitable mitigation measures, and whether some sites should be built on at all.

This Q&A is adapted from the Planet Earth Podcast, 4 March 2014. The full podcast and transcript are on Planet Earth Online. http://planetearth.nerc.ac.uk/multimedia/story.aspx?id=1632