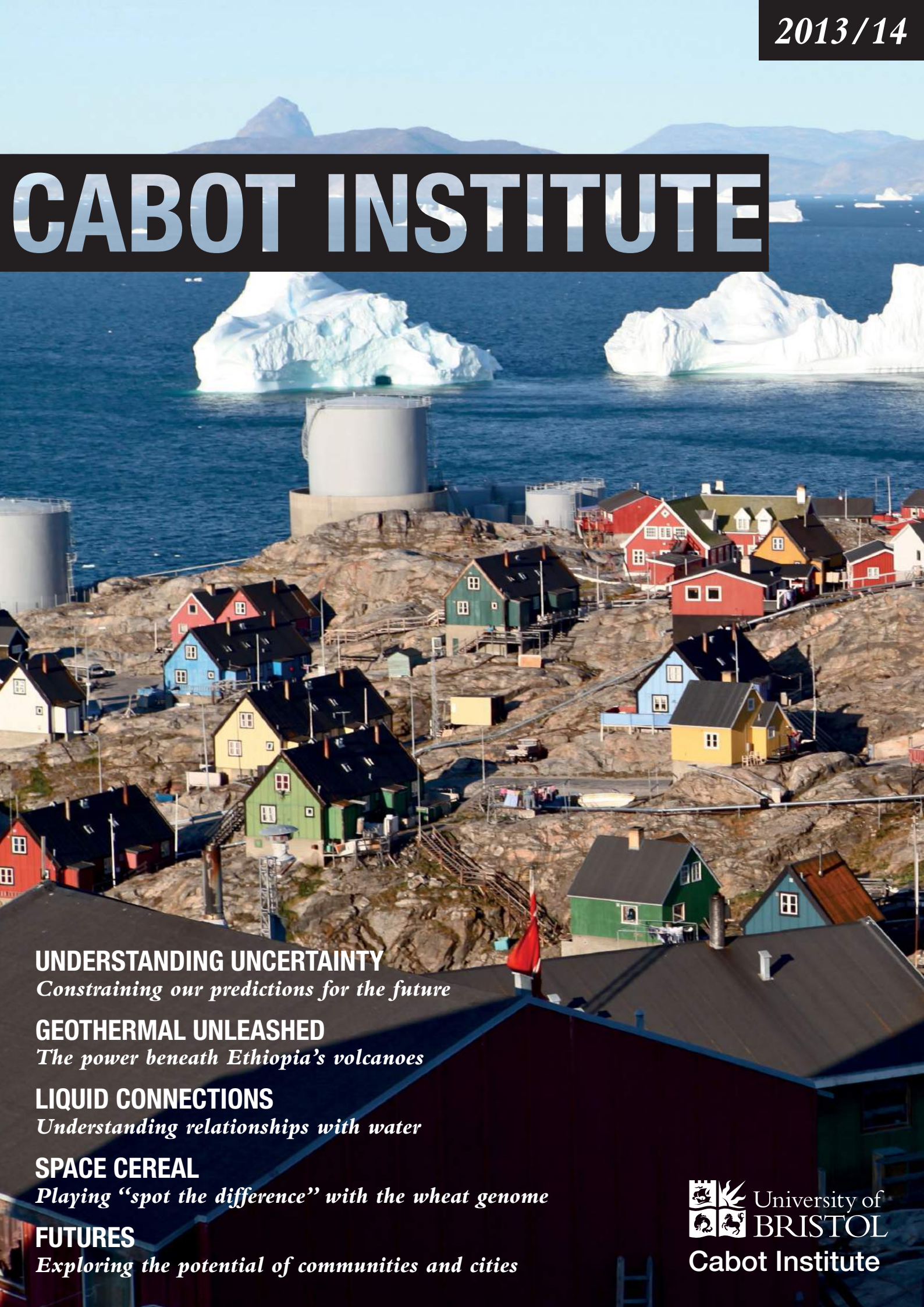
2013/14

CABOT INSTITUTE



UNDERSTANDING UNCERTAINTY
Constraining our predictions for the future

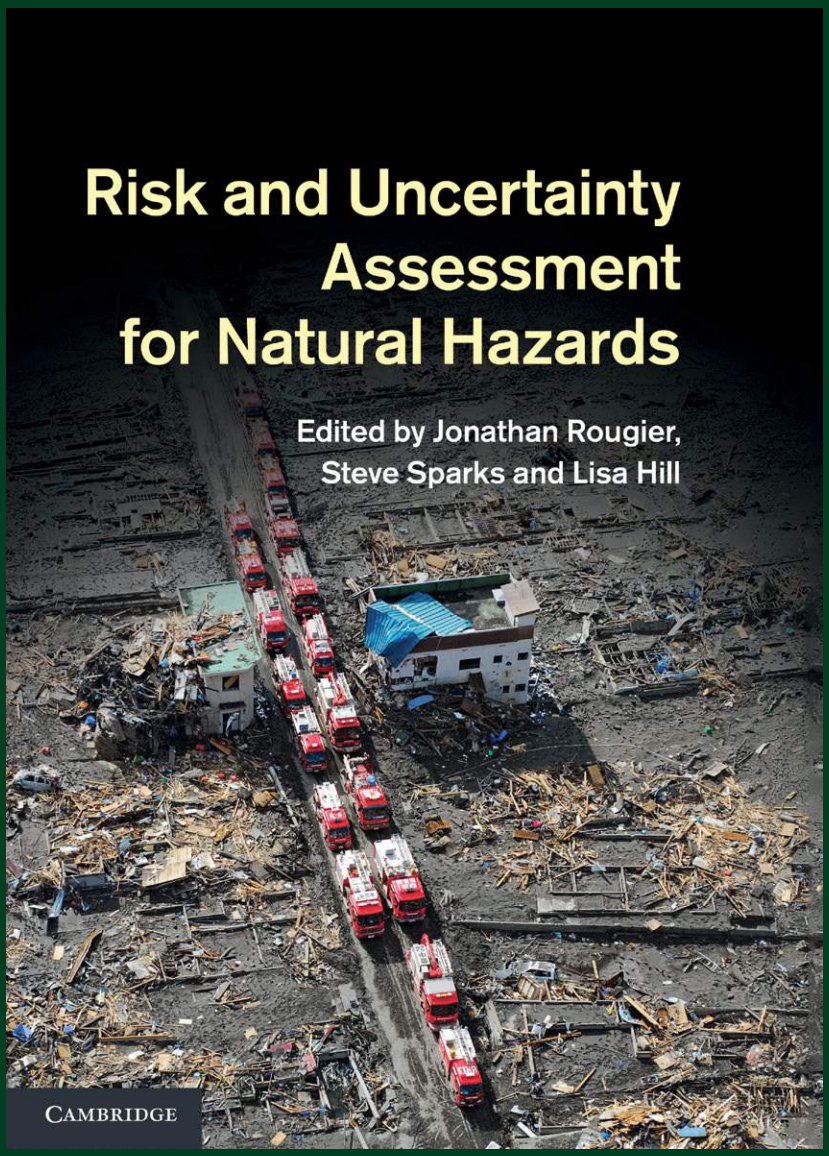
GEOTHERMAL UNLEASHED
The power beneath Ethiopia's volcanoes

LIQUID CONNECTIONS
Understanding relationships with water

SPACE CEREAL
Playing "spot the difference" with the wheat genome

FUTURES
Exploring the potential of communities and cities

University of BRISTOL
Cabot Institute



CONTENTS

Editor
NICOLA TEMPLE

Nicola is an independent science writer who has been working with the Cabot Institute to capture the stories of our research and its impacts. In 2013, with the support of the Institute, Nicola joined Bristol geophysicists on the volcanoes of Ethiopia to learn how their research may help geothermal development (see story on page 10).

Cover image: Uummannaq, Greenland – a community living with melting ice (see more on page 8). Credit: Mathieu Depoorter & Fanny Leroy.

WELCOME

Credit: Philippa Bayley

Prof Rich Pancost (left), Prof Sir John Beddington (middle) and Prof Paul Bates (right).

Message from Prof. RICH PANCOST CABOT INSTITUTE DIRECTOR

Welcome to the second annual issue of the Cabot Institute magazine. It has been an exciting and transformative year for the Institute, marked by new appointments, new achievements, and relentless progress in our mission to understand, adapt to and live in a world with increasing environmental uncertainty.

The most exciting expansion of the Institute is the recent appointment of former UK Government Chief Scientific Adviser, Professor Sir John Beddington, as Chair of our Advisory Board. Sir John formally started his post in May 2013 and since then has met academics at Bristol with interests ranging from the legal regulation of biodiversity to monitoring greenhouse gas emissions, as well as chairing termly Advisory Board meetings. We are proud to have Sir John as part of the team, but we are particularly benefitting from his knowledge and experience. Each visit stimulates new ideas and potential collaborative linkages.

The other major change is that Paul Bates stepped down as Director to lead the School of Geographical Sciences. Paul's 3-year tenure has been marked by sustained growth and expansion of the Institute, including the initiation of new partnerships with the Environment Agency and Fera, several large grants to study hazards, risk and uncertainty (and you can read more about those elsewhere in the magazine), and a string of awards. The Cabot Institute was a partner in the City of Bristol's successful bid to become the European Green Capital 2015 and we have hosted numerous, high profile public events attended by over 6,000 people. These are big shoes to fill, but Paul's research and his new role keep him firmly in the Cabot Institute family and we will not be losing his experience and wisdom.

It is in this context, that I eagerly look forward to my first year as Director. My research interests are in past climate reconstruction, and I have led a Biogeochemistry research group in the School of Chemistry for the past 13 years. I have been a passionate supporter of the Institute since its inception, and until recently led the Global Change research theme under the Cabot Institute. I firmly believe that the breadth and depth of Cabot Institute research, combined with a strong core team and excellent partnerships, can positively impact the significant environmental and societal challenges we face.

My vision for the Institute is to ensure that environmental uncertainty becomes a central component of framing policy. Environmental uncertainty is not an opaque label for things "we do not understand" and by an extension it is not a cause for inaction. It is a tool for constraining our predictions and is the platform for robust and informed decision-making. Consequently, our focus remains on obtaining new funds to enable new interdisciplinary research initiatives and, perhaps most importantly, to train a new generation of political and scientific leaders with the skills to weld these statistically-constrained predictions to adaptation and mitigation strategies. This requires continued investment and an increasingly outward looking portfolio of Cabot activities. Over the next year, we hope to see you in Bristol and beyond, in London and across the UK, and in the media (including social media) discussing science, building future cities and debating policy. ■

Prof. PAUL BATES FORMER CABOT INSTITUTE DIRECTOR

It has been a real privilege to be the first Director of the Cabot Institute and to see it through its early years. To get to this point has taken enormous commitment from a huge number of people and I think that the appointment of Sir John signals the ambition and determination at the University of Bristol to develop a world-leading environmental institute. I'd like to thank the Cabot team for making my time as Director so hugely enjoyable, and for embracing my only management "rule": "we're here to do a serious job, but we're also going to have fun". Long may it continue.

Prof. Sir JOHN BEDDINGTON CHAIR OF THE CABOT INSTITUTE ADVISORY BOARD

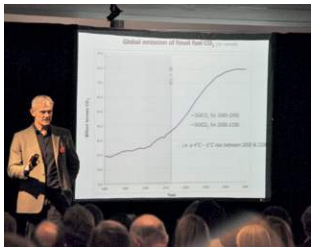
We face huge, complex and interlinked environmental challenges that can only be tackled by researchers coming together across disciplinary boundaries. The Cabot Institute is an inspiring example of this kind of collaboration, and I look forward to working closely with them.

IMPACTS

The Cabot Institute brings together world-class expertise, developing truly multidisciplinary research programmes to tackle the challenges of uncertain environmental change. The research that is conducted and the events that we hold all contribute to the University of Bristol's international reputation. Here we highlight our impacts within the University, our region and across the world.

Challenging public behaviour and opinion on climate change

Over 13,000 people across the world have watched our 2012 Annual Lecture with Kevin Anderson from the Tyndall Centre, sparking debate and realisations about human consumption and the effects on environment and society. Watch again **bristol.ac.uk/cabot/events/2012/194.html**



Credit: Darren Hall

Making oil's presence more visible

Renowned artist Neville Gabie worked with academics across the Cabot Institute to demonstrate how oil is deeply embedded in all of our lives. See one of Neville's images on page 23. **bristol.ac.uk/cabot/people/air/**

Credit: Neville Gabie

Helping Bristol win European Green Capital 2015

The Cabot Institute played a role in supporting Bristol's bid for European Green Capital and will help to deliver the 2015 year and its legacy. The award will help make Bristol a safer, greener and better place to live and work whilst growing the green economy and green business.

BRISTOL GREEN CAPITAL
INSPIRING CHANGE

Research grant success

Cabot Institute researchers gained further significant grant funding for their research, including five European fellowships for researchers in volcanology, biodiversity and hydrology. Further support from the Research Councils is enabling new research that directly benefits communities - developing new digital apps for energy efficient homes, enabling communities to navigate green legislation, and providing decision-makers with better tools for understanding risk and uncertainty in the changing environment.

Training the next generation

Two Cabot Institute-supported Masters courses have recruited more students than ever before - the MSc in Environmental Policy and Management and the MSc in Climate Change Science and Policy. These students will be able to work with local organisations to build their skills and understanding of the UK environmental sector.

Credit: Amanda Woodman-Hardy

More efficient flood prediction

Professor Paul Bates won the Lloyd's Science of Risk Prize for his work on flood modelling. The impact of the paper's publication is already being felt by the insurance industry with flood models based on the equations outlined in the paper under development by academics and specialist companies (see story on page 14).

Credit: Paul Bates

Linking nuclear policy with technology

We brought government, industry and academia together for our Nuclear Futures conference - linking policy and technology. The event brought a social and political context to new technology development, and helped to identify specific areas for joint work. **bristol.ac.uk/cabot/events/2013/245.html**

Credit: Philippa Bayley

Working closely with industry to shape future communities

The University has signed a Memorandum of Understanding with global design, planning and engineering company Arup. We have committed to work together on collaborative research projects to drive innovation, address societal challenges, develop talent and create opportunities for knowledge transfer, focussing on the area of future communities.

Credit: Martin Chainey

Understanding how humans are causing a new geological age

In the Anthropocene, humans are the dominant force shaping the planet. We brought together academics from around the world to evaluate the role and value of the social sciences in understanding this new geological age. **bristol.ac.uk/cabot/events/2013/206.html**

Credit: Philippa Bayley

Collaborating near and far

The Cabot Institute is part of a coalition with Durham University, UCL and Kings College London to share complementary expertise in the science and social science of natural hazards, risk and resilience. We are also linking up with our partner environmental institutes across the South West - at Exeter, Cardiff and Bath - known as the GW4. Further afield, we are pursuing research relationships with Kyoto University, particularly the Disaster Prevention Research Institute, with joint projects in volcanology, hazard modelling and loss estimation.

Credit: Philippa Bayley

Building a solar powered city

Cabot Institute member James Lancaster has helped set up Bristol Solar City, a broad coalition of solar organisations with the aim of installing 1GW of solar energy in Bristol by 2020. **bristolsolarcity.com**

Credit: Bristol Solar City

Reducing scientific uncertainty about climate change

Cabot Institute researchers made significant contributions to the authoritative Intergovernmental Panel on Climate Change Working Group 1 report, assessing the physical scientific aspects of the climate system and climate change, which was published in September 2013. Professor Tony Payne was a lead author for the chapter on sea level change, and Professor Jonathan Bamber was a review editor for the chapter on the cryosphere. **bristol.ac.uk/news/2013/9764.html.** Cabot Institute researchers are also leading on chapters in the Working Group 2 and 3 reports, which address climate change impacts and policy responses.

Credit: IPCC

MELTING UNCERTAINTY

Understanding uncertainty, and communicating the extent of it effectively and rigorously to people who use scientific data and models is the bedrock of Cabot Institute research. Here we look at a number of ways that Institute researchers are getting to grips with uncertainty and telling others about it - from expert elicitation to blogging.

Credit: Mathieu Depoorter & Fanny Leroy

Ice2sea: reducing uncertainty around future sea-level rise

The European coastline boasts many unique and critical habitats - from marine turtles nesting on the beaches of Cyprus to rare and endangered liverworts nestled between coastal sand dunes of Wales. It is also here, in these coastal regions of the European Union, that over 205 million people make their homes and livelihoods (2008 estimate). The future and prosperity of these regions is threatened by sea-level rise, yet there is major uncertainty associated with projections for how much sea level will rise and over what time frame.

One of the greatest sources of uncertainty is around how much ice sheets and glaciers will contribute to the rise in sea-level. Greenland and the Antarctica ice sheets contain around 99.5% of the Earth's glacier ice and if they were to melt completely, global sea levels could rise as much as 65 metres. In 2007, the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) identified this major source of uncertainty and in response a scientific programme, known as ice2sea, was funded by the European Union to address the issue.

Ice2sea is a collaboration of 24 research institutes from around the globe that is coordinating the efforts of experts from a wide range of disciplines. Using fieldwork, satellite observations and computer simulations, the ice2sea programme has helped improve our understanding of how ice sheets and glaciers might contribute to sea-level changes in the future - reducing the uncertainty and improving projections.

Jonathan Bamber, Professor of Physical Geography at the University of Bristol, is part of ice2sea and has provided some of the satellite information and other data sets that have been critical to the modelling work. He's also responsible for integrating the results from the different programme areas into a coherent story that will ultimately help produce the most comprehensive projections of regional sea-level rise to date.

"Collectively, the ice2sea project has advanced our understanding of how terrestrial ice will affect future sea-level rise more than any other single project ever has," said Bamber.

Other Bristol contributors to the project include Professor Tony Payne (Professor of Glaciology), Dr Tamsin Edwards (Research Associate) and Mr Mathieu Depoorter (PhD Student), all from the School of Geographical Sciences.

The new improved projections of sea-level rise from the ice2sea project have contributed to the 2013 IPCC report and have been given to European policy makers, providing a sound scientific basis for policy development and coastal defence planning. ■

Nicola Temple

Understanding and communicating uncertainty

Over the next twenty years, a warming of about 0.2°C per decade is predicted for a range of Intergovernmental Panel on Climate Change (IPCC) emission scenarios. By the end of the century, the IPCC projects a global sea level rise of 18 to 59 centimetres. A dangerous combination of rising seas, sinking land and growing coastal development is likely to increase global flood damages from £3.8 billion per year today to £630 billion per year by 2050. What lies between this range, from £3.8 billion to £630 billion, is known as uncertainty; a concept that fuels sceptics but is critical when communicating climate science.

What is uncertainty?

Researchers use uncertainty to express what they know, what they don't know and how confident they are about these judgements. No question can be answered with 100 per cent certainty and even widely accepted theories can be challenged by new evidence. Uncertainty is particularly important in climate science, where climate models form the basis of important and costly policy decisions. The IPCC use a "likelihood scale", which links uncertainty and probability with everyday language. For example, a statement that it is "very likely that humans exert a strong control on the climate", means scientists judge there is a 90% probability (or greater) that this is true.

Understanding uncertainty: sea level rise over the next century

One of the most important predictions in climate science concerns the stability of continental ice on Greenland and Antarctica. The Fourth Assessment Report of the IPCC (AR4) identified many shortcomings in the capability of the scientific community to make robust projections of the contribution of ice sheets to sea-level rise, necessitating research programmes such as ice2sea. Postdoctoral researcher on the ice2sea programme, Dr Tamsin Edwards, explains that "...the difference with the ice2sea project is that it took a really broad approach by pinning down the contribution from all forms of land ice - which hadn't really been done before in such a consistent way". The EU-funded team conclude that there is a 1 in 20 chance that melting ice would drive up sea level by more than 84cm; put another way, that there is a 95% probability sea level will not rise above this figure. These values have not changed enormously when compared to previous IPCC estimates, but they are an important new assessment of uncertainty in light of improved understanding of the ice sheets.

Dr. TAMSIN EDWARDS

Communicating uncertainty: the role of the scientist

Edwards is driven by constraining uncertainty in her climate models, and making the science as transparent as possible for interested public and policy stakeholders. Communicating uncertainty is also important in other disciplines that are concerned with risk and hazard assessment (e.g. volcanic eruptions, earthquakes and flooding). To bring those researchers together Edwards recently organised a two-day Black Box Workshop, examining multidisciplinary approaches to uncertainty. This event helped researchers share common understandings and develop new methodologies and approaches. Edwards also helps inform and engage the public about uncertainty through public events and social media. At the Cheltenham Science Festival she led an event - "Can we trust climate models?" - with climate "agnostic" Professor Jonathan Jones and government science advisor Dr Claire Craig, which was attended by a crowd of more than 300 people. Edwards also discusses uncertainty on Twitter (@flimsin), via her blog "All models are wrong" (blogs.plos.org/models), and in the comment sections of well-known climate blogs. ■

Gordon Inglis

Credit: Mathieu Depoorter & Fanny Leroy

Calving event filling Store fjord.

Estimating uncertainty through expert elicitation

In 2010, Professor Jonathan Bamber (School of Geographical Sciences) and Professor Willy Aspinall (School of Earth Sciences), both part of the Cabot Institute, invited leading experts in glaciology from around the globe to provide detailed judgement on their understanding of the processes and drivers acting on Greenland and Antarctica ice-sheets and how these ice-sheets might behave under these influences over the next century.

The approach is known as structured expert elicitation and it uses the opinions from experts and combines them in a mathematically rigorous way to produce an assessment of probability. It is, essentially, another approach to estimating uncertainty.

The thirteen experts were then provided the same main questions two years later to assess whether their views had changed, and if so, how.

Bamber and Aspinall found that the experts collectively perceived a low, but not insignificant, probability that ice-sheets could contribute to sea-level rising more than a metre by the year 2100. These data reflect an opinion among experts that there are still too many unknowns about the processes at play and how the ice-sheets themselves will respond in the future to put an upper limit on the rate of sea-level rise in this century. This information is not fully captured by the models themselves, and when combined with the model predictions, this pool of expert opinion gives a more robust assessment of uncertainty.

The study was published in Nature Climate Change (3, 424-427 (2013)).

Living with melting ice

With 17,000 inhabitants, Nuuk (the capital of Greenland) gathers a quarter of the Greenlandic population. Migration from the small villages is high there and follows the rapid socio-economical changes of the Greenlandic society. The vast country (the largest island on the planet) has a tiny population of 57,000, and is trying to develop its economy by opening its land to international mining companies.

In the height of summer, calving events - where ice chunks break away - from the Store glacier literally fill in the fjord. Combined with a sudden wind chill from the icecap, this pack of icebergs and bergy-bits (mini icebergs) can quickly consolidate, leading to hazardous navigation.

Uummannaq is a small rocky island located in the middle of a game-rich fjord along the West coast of Greenland. Around 2,000 people and twice as many dogs live here in almost complete isolation from the rest of the world. When the sea ice is weak, seal hunters and fishermen are stuck on the island. Because of warmer temperatures and an increased number of storms, the sea ice has been weak for many consecutive years, which has left hunters with no option but to kill a great number of their unnecessary sledge dogs. If the sea ice was to completely disappear in winter, a big part of the Uummannaq culture would disappear too. Here the conditions are harsh and Greenlanders live on the edge. Nevertheless people are optimistic and enjoy the stunning scenery of passing icebergs.

MATHIEU DEPOORTER & FANNY LEROY

These images of Greenland (including the front cover) were taken by glaciology PhD student Mathieu Depoorter and journalist Fanny Leroy on a field trip in 2012. While the future may be uncertain, these images tell the stories of communities today living with melting ice and a changing climate.

Credit: Mathieu Depoorter and Fanny Leroy

PLAYING WITH WIRE

The technologies and services of the future, which will be needed for improved environmental monitoring, urban planning, and transportation and energy management will require a level of communication that existing networks are unable to provide. Learn how Bristol is leading the way with a city-scale digital infrastructure that will become the testing ground for new technologies and applications.

Are you getting enough fibre?

The UK took the decision to switch off analogue TV and switch to full digital delivery years before any other country. The impact was an immediate market imperative. UK company Pace is now a £2.5 billion turnover manufacturer of set top boxes, the BBC are a world leader in digital content delivery and UK digital TV technology, and production industries are booming. The lesson here is that countries first to commit to so-called "enabling" infrastructure create opportunities for innovation and growth, including in the environmental sector.

A revolution is taking place in global communications as new fixed and wireless technologies and standards emerge and are deployed, enabling super fast data transmission. The UK has fantastic academic, innovation and industry communities in wireless and fixed communications, both technology and applications; however, "Singaporean" has become the byword for exemplar connectivity. UK service networks lag behind the world's best and struggle to support large-scale testing and experimentation.

All this is changing in Bristol. In the 1990s, Bristol City Council took a farsighted decision to buy cable TV operator Rediffusion's ducting network - the pipework used to route communications network fibre and cabling around the city. The Council have progressively replaced copper wires with optical fibre and built a network for internal communications to enable infrastructure. This network currently saves £2.5 million per annum and is the most extensive, publically-owned and accessible network in any UK city outside London. It creates the opportunity to deploy new infrastructure at a fraction of the cost for any other European City. Furthermore, within the City Council, the digital agenda is managed by the Futures group, which also addresses "creative, smart, green and connected" agendas, helping to ensure unparalleled linking of activity across sectors.

Using the underlying infrastructure and £4.3 million from the Government Urban Broadband Fund, the City Council is collaborating with the University of Bristol to design and build the UK's fastest city-scale fixed and wireless network purely for research, experimentation, development and testing purposes. The network will allow the deployment of communications technologies far beyond 5G and enable academic, business, the public sector and communities to develop the applications of the future. Bristol will have the potential to become a world-leading hub for communications with all the economic and societal benefits. Led by Professor Colin Taylor of the Cabot Institute's "future cities" theme, the University will be trying to shape technologies and infrastructure around people and their sustainable behaviours, rather than putting the technologies themselves in the driving seat.

Capitalising on the fibre network, users will be able to access unlimited bandwidth, and share vast amounts of data, with multiple environmental applications and benefits. High performance networking, wireless communications, distributed high performance computing and an "Internet of Things" will enable efficiencies in urban planning and energy management. Sensors of all types, 3D printers, displays, projectors, venues, locations will be connected, enabling improved environmental monitoring and less carbon-intensive transport. Even the computers for the network are recycled - the University's supercomputer Blue Crystal 2 will be added to the network when it is released from its climate modelling duties.

The call is now open for groups to come forward who can see opportunity and benefit from this city-scale platform. These first users will inform the detailed design for the initial network and the roadmap for future development. There are no preconceptions and few limits. Imagine where Bristol will go. ■

James Lancaster

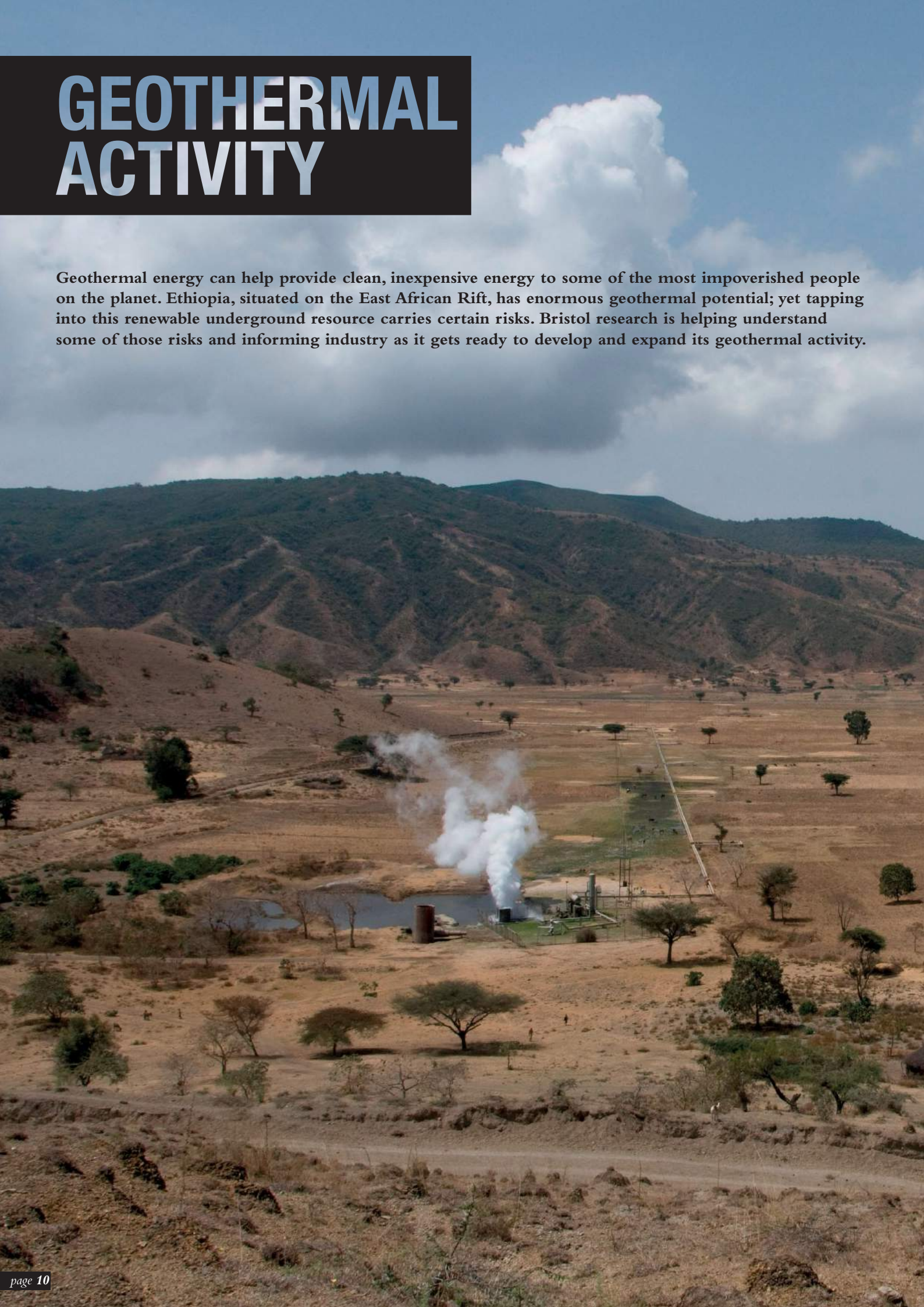
Digital Green Doors

Dr Chris Preist , Dr Elaine Massung and Daniel Schien, of the Department of Computer Science, are just some of the researchers looking to exploit digital technologies to support social and environmental innovation. Since 2010, Bristol Green Doors has been offering members of the public the chance to learn about what can be done to their homes to make them more energy efficient by running events where householders who have already made energy smart improvements open their doors to the public - Green Open Homes. Schien has now developed a new smartphone app that allows users to see where the energy efficient houses are located and which retrofitting measures have been installed, and Massung and Preist have been testing its implementation. The app can be used to find houses with specific measures, save houses to a shortlist, and contact some householders with queries after the event **cabot-institute.blogspot.co.uk/2013/10/bristol-green-doors-measuring-impact-of.html**

Bristol GreenDoors
PEOPLE LEARNING ENERGY HOMES

GEOTHERMAL ACTIVITY

Geothermal energy can help provide clean, inexpensive energy to some of the most impoverished people on the planet. Ethiopia, situated on the East African Rift, has enormous geothermal potential; yet tapping into this renewable underground resource carries certain risks. Bristol research is helping understand some of those risks and informing industry as it gets ready to develop and expand its geothermal activity.



Notes from the field: From great turmoil comes great power

There's no sign of a road; we're driving through water and are guided only by rows of cacti that separate the mud huts in this village. Heavy rains overnight have transformed this dusty path we drove just yesterday. The local children are still here though, running alongside us yelling "Ferengi"; the word means foreigner here in Ethiopia.

I'm with a small team of researchers from the University of Bristol and Addis Ababa University and we are roughly 155 miles (250km) south of Addis Ababa, headed to a small village on the rim of the Corbetti volcano crater. The research team is here to establish GPS stations here on Corbetti as well as the neighbouring volcano of Alutu. These volcanoes have no permanent monitoring equipment, no eruptive history and are assumed to be dormant. However, the team is here because they've seen signs that these volcanoes may not be as dormant as once thought.

Geological turmoil

Dr Juliet Biggs, Lecturer in the School of Earth Sciences at Bristol, has been using satellite images to study the East African Rift zone - a 6,400 km fracture in the Earth that runs through Djibouti, Ethiopia, Kenya, and Tanzania. This fracture is splitting apart by nearly an inch every year, allowing magma to intrude into the Earth's crust, and forming nearly 100 volcanoes along this rift over the last 10,000 years.

By comparing images taken from space at different times, Biggs is able to calculate deformations - inflations and deflations - in the Earth's crust. Her results show that two volcanoes - Corbetti and Alutu - have had significant uplift episodes, lifting as much as 15cm in a single year.

"These deformations are typically attributed to the movement of magma below the surface," said Juliet, "and can be interpreted as a sign of unrest."

This is what has brought Juliet and her crew to Ethiopia. The ground-based monitoring equipment that they are deploying will collect a GPS signal from the satellites every 15 seconds. Juliet will then use these data to develop a better understanding of these deformations in relation to the rift's overall movement and ultimately the geological processes that are happening here.

Working in the field

When we arrive at the site, Juliet speaks to the head of the family, Nure, through Tulu, the only one of the four member team that speaks the local Oromo language. She explains what they are doing and Nure is keen to help.

The next challenge is to get all the equipment up the steep hill. A small crowd of local villagers have gathered and they help take the load. Car batteries, drills, solar panels and other equipment are loaded onto shoulders and under arms, while the smaller children run ahead to show us the least treacherous route.

Credit: Nicola Temple

Matthew Wilks and Dr Juliet Biggs set up the GPS receiver at one of the monitoring sites in Ethiopia.

The team gets to work quickly before the heat of the day sets in. They must first drill a hole into the rock, which is black obsidian - a type of volcanic glass that is formed when lava cools very quickly. This is where the GPS antenna will be mounted and the team works swiftly to set the mounting pin level in the hole before the glue dries in the intense sun. With the antenna mounted and aligned, the data recorder is programmed and hooked up to the solar panels and a car battery.

Nure has agreed to guard the station and gets his family and friends to collect acacia branches that will serve as a fence to discourage livestock from investigating the equipment. He also informs the team that there is a troop of curious baboons that frequent the area. This presents a new challenge for the team and they take extra caution to pile rocks around the equipment to protect it.

Unleashing the power

The data Juliet and her team collect over the next year will help fill a significant void of information about the potential hazards associated with these volcanoes and the risks to people, like Nure and his family, who farm the lands in and around these calderas.

However, these data are also being collected at a time when geothermal energy is set to expand in Ethiopia. Deep borehole drilling is expected to start on both Alutu and Corbetti in the next year. Alutu already hosts five productive geothermal wells, but is preparing to expand by 70 MW over the next decade through the addition of more wells. While Corbetti is yet to be explored, the industry predicts that this field could become one of the world's largest geothermal sites.

The wells on Alutu descend over 2 km into the Earth and tap into aquifers with temperatures around 300°C. The water in these aquifers is heated by the surrounding rock, which has itself been heated by magma seeping up through cracks in the Earth's crust. The steam released from these wells then drives turbines that can deliver clean, renewable energy. However, drilling to these depths can be risky.

"We know from the fracking industry that these activities can put stresses in the ground, and cause micro-earthquakes and changes in the circulation patterns of the groundwater," said Juliet. "So we're interested to see what effects the drilling and the increased geothermal production may have on the natural system that we already know is experiencing big deformations."

Juliet and her colleagues are working with the geothermal industry and in August brought industry and academics together in Bristol, with support from the Cabot Institute and the Natural Environment Research Council, to share information and look for synergies that can improve geothermal production and reduce risk and uncertainty associated with its development. ■

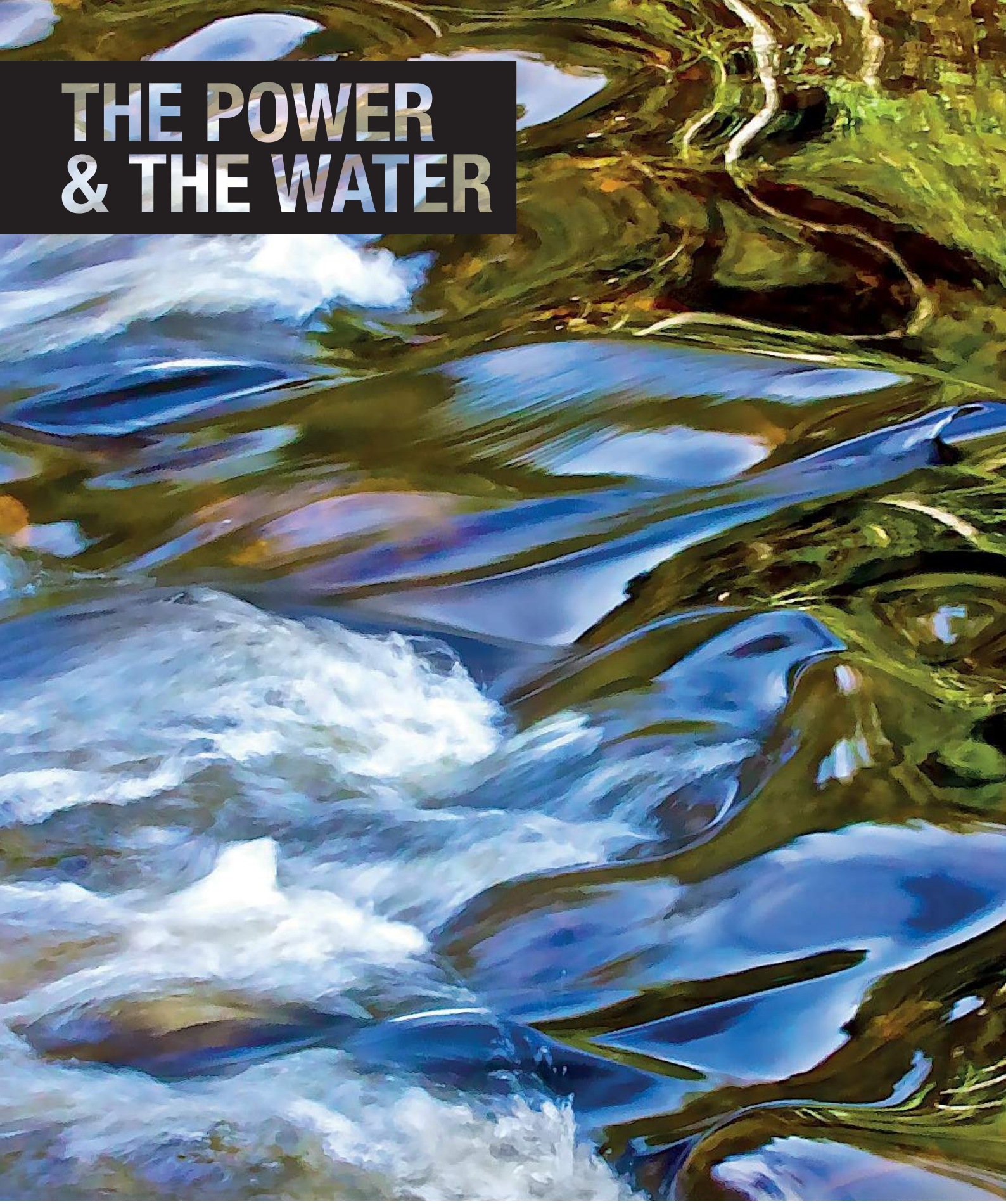
Nicola Temple

About the workshop

On 19 August 2013, the Cabot Institute, University of Bristol and Natural Environment Research Council hosted a 2-day workshop aimed to improve the links between academic research and the geothermal industry in East Africa. The workshop was an enormous success with industry representatives from Ethiopia, Iceland, Kenya and the UK attending, along with academics from the UK and Ethiopia. Participants shared information about the data being collected in regions of geothermal development and a best practices guide is currently being developed based on the workshop outcomes. The guide will discuss the linkages between geological research and industry that can accelerate growth in the East African geothermal sector, as well as provide suggestions on developing strong links between industry and the academic community.

Photo left: A geothermal well, located in the caldera of the Alutu volcano in Ethiopia, is being vented to release pressure. (Credit: Nicola Temple)

THE POWER & THE WATER



Credit: Nicholas Howden

Water is both a vital resource and a major environmental hazard. We drink it, draw energy from it, use it for transportation and build our communities around it; yet it can also harbour disease, flood our homes and destroy entire communities. It is a complex relationship that is being explored in many ways by Bristol researchers - from building decision-support tools to predict and manage risk around flood and tsunamis, to understanding our interactions with and attachments to our waterways.

Connecting pasts and futures

What are our connections with water? How have they changed over time? How do our relationships with water evolve and how do they affect our perceptions and attitudes toward water management? These are the types of questions being asked as part of a three-year project called The Power and the Water: Connecting Pasts with Futures, which started in October 2013 and is funded by the Arts and Humanities Research Council. Peter Coates, Professor of American and Environmental History in the University of Bristol's Department of History, is the principal investigator for the project, which involves investigators from the University of East Anglia and the University of Nottingham.

Coates and his team at Bristol are focussing on river systems and their linked bio-physical, energetic, commercial and cultural flows. In the west, the Bristol team will be investigating the liquid history of the Severn River, and in particular, the debates through the decades over harnessing tidal energy in the Severn's estuary. In the east of England, the team will be exploring the past, present and future of the River Tyne, and working with Northumbrian Water as they prepare their next 5-year management plan. The projects begin at a timely moment for water and energy research, when there is growing consensus that freshwater is not only our most precious natural resource, but also the most threatened.

By drawing on historical relationships, the Bristol team will be able to shed light on people's reactions to proposed or anticipated changes, distinct from responding to actual changes. The proposal for the Severn Barrage, for example, is firmly ensconced within debates about renewable energy. Advocates of the project claim that estuarine tides will generate power equivalent to one nuclear power plant whilst also helping the UK tackle climate change and reduce carbon emissions. Those opposed to the project claim the environmental impact is too high and the potential costs do not outweigh the potential benefits.

Prof..
PETER COATES

It's a debate that has been regularly revived since the 1920s. The Bristol research will hopefully shed light on how different interest groups project imagined impacts into the future, based on values invested in current and past environmental conditions and experience.

"We hope that our research findings will help managers and policymakers understand the perceptions and cultural interpretations that act as levers or barriers to water management," said Coates.

Environmental historians, such as Coates, contribute to our understanding of environmental challenges by situating them within the wider social, economic, political, cultural, scientific and technological contexts and identifying how environmental change has been given different meanings by different societies, different people, in different times or places, and in different contexts. A good deal of research on environmental questions tends to be driven by the imperative to universalize and systematize knowledge about human interactions with "the environment". Yet approaches used by the arts and humanities to interpret qualitative data suggest that there's a great deal of meaning in the specifics – both in time and place – of how relationships are woven between particular places and particular people for particular reasons. ■

The Tsunami factor: developing multi-hazard models to assess earthquake risks

Large earthquakes, such as the 2011 Tōhoku event, have many cascading catastrophic effects; after the mainshock there may be aftershocks, ground failures, fires, and tsunamis, which lead to loss of lives, injury and direct physical and financial losses, which greatly impact society. Understanding the risk, both physically and financially, associated with such a large event is very challenging, but necessary in order to implement effective mitigation measures. However, to date, decision-support tools that help put value to these potential losses have not integrated the multiple hazards into one comprehensive model; modellers working on ground-shaking hazard and modellers working on tsunami hazard will each produce their own risk estimates, failing to capture the inherently linked nature of these events.

However, Katsu Goda, Senior Lecturer in Civil Engineering at Bristol and member of the Cabot Institute, is trying to change this by developing a multi-hazard model. In spring 2013, Goda travelled to Kyoto University in Japan to work with the Disaster Prevention Research Institute in order to validate his tsunami simulations using data from the 2011 Tōhoku earthquake event. Goda was part of the Earthquake Engineering Field Investigation Team that surveyed Tōhoku after the tsunami and has witnessed the devastating effects first-hand.

"Looking at the damage made me realise that more needed to be done," said Goda. "This is why I'm working towards a multi-hazard seismic assessment, which incorporates the risk associated with earth movements as well as the risk of a tsunami."

Goda's approach is novel in that it considers multiple earthquake slip models - which describe the amount, distribution and timing of the slip associated with an earthquake. These slip models are obtained from various analyses that have used seismic, tsunami and geodetic data to estimate earthquake slips along a fault plane. Goda found that the different models have a major influence on the tsunami simulation results. By considering multiple models in his analysis and assessing their tsunami prediction results, Goda is able to quantify the unreducible uncertainty associated with these predictions, and ultimately set a benchmark for all other tsunami predictions using the extensive data from the Tōhoku tsunami. The tsunami simulation tool will be incorporated into cascading mainshock-aftershocks ground-shaking models, which Goda has developed as part of a comprehensive multi-hazard earthquake simulator.

Goda was awarded the prestigious 2012 Charles F Richter Award of the Seismological Society of America in recognition of his outstanding contribution to the goals of the Society as an early career researcher. ■

Credit: Mark Simmons

Dr.
KATSU GODA

A blueprint for flood risk management

Predicting flood inundation has become a whole lot easier... ten-fold easier to be exact. Improvements in a 2D flood inundation model developed at the University of Bristol mean flood inundation scenarios can be simulated at a 5 m scale in less time and with less computer power than current industry models simulating at a 50 m scale. At this finer 5 m scale, the model can simulate flow around buildings and in urban areas, which has led to significant advancements in the predictive tools used to generate national flood maps, assess flood risk and estimate flood damage.

The model, LISFLOOD-FP, was developed by the Cabot Institute's outgoing Director and Professor of Hydrology at Bristol, Paul Bates, and it has become a blueprint for the multi-million pound flood risk management industry that impacts tens of millions of people each year.

The power of Bates' LISFLOOD-FP model lies in its relative simplicity. Prior to its development, it was thought that better predictive models required complex physics equations, which in turn required more computer power to solve. However, in the 1990s, Bates decided to re-think the physics behind the models. He joined his friend Dr. Ad de Roo of the EU Joint Research Centre in Italy and for three months the colleagues worked to develop a new flood inundation code.

"Instead of looking at including more and more complex physical processes, we turned that modelling paradigm on its head and asked 'what's the simplest model that matches the available data and still allows us to predict what we want'," said Bates. "We found that the way to improve the predictive skill of the model was not to load more physics in, but to work out what was the minimum physics required to simulate the processes of interest that then allows the model to run on the finest grid possible over the biggest area."

Since the 1990s, Bates and his colleagues have made many improvements to their model and with each step they have openly published their advancements, building a blueprint for both academic and commercial code developers and saving industry years of developer time.

The impact of Bates' modelling work was recognised by industry in 2012 when he was awarded the Lloyd's Science of Risk Prize in the category of Natural Hazards. This year, Bates and his colleagues, Dr Jeff Neal and Dr Gustavo de Almeida also from Bristol's Hydrology Research group, won the 2013 Vice Chancellor's impact award for their work on LISFLOOD-FP. The award recognises innovative research that has societal benefits. ■

Nicola Temple

Prof. PAUL BATES

Dr. DAI YAMAZAKI

Alumni-supported fellow at the Cabot Institute

Cabot Institute research fellow, Dr Dai Yamazaki, is a hydrologist looking at global hydrology and water resources. Yamazaki conducts realistic simulations to help predict river discharges, water levels and flooded areas at a global level by extensively processing satellite measurements of rivers and floodplains. He hopes his work will help global water resource managers and flood/drought forecasting. Yamazaki received his Cabot fellowship from alumni donations, supplementing a fellowship from the Japan Society for the Promotion of Science. This funding has enabled his work to have more impact on industry and society. You can read his recent paper "Global Flood Risk under Climate Change" at **nature.com/nclimate/journal/v3/n9/full/nclimate1911.html**

Credit: Paul Bates

Temporary flood defence structures at Upton-on-Severn in the summer of 2007.

CULTIVATING FOOD SECURITY

Food security is another major challenge that Cabot Institute researchers are addressing. From efficient and sustainable rearing of animals to unravelling the wheat genome, Bristol is collaborating with partners around the UK and around the world to help improve future farming systems.

Prof. **MARK EISLER**

Dr. **MICHAEL LEE**

The future of sustainable world farming: "the right animals in the right system"

When it comes to rearing animals for food, the US-based model of livestock farming has been the industry standard. While this system of farming produces a high yield, it relies heavily on grains - crops increasingly needed to feed humans - and few countries have a surplus.

In a world with finite land and resources, and an ever-increasing global population, more sustainable methods of producing livestock must be found. Two University of Bristol researchers are doing just that. Professor Mark Eisler and Dr. Michael Lee of the Veterinary School are spearheading an international collaboration to look at maximising livestock production efficiency through more suitable feeding systems. The project is funded by the World Universities Network (WUN) and is in partnership with the Cabot Institute and the Food Security Land Research Alliance.

Producing more efficient animal protein

With the intensive US farming method - known as Total Mixed Ration (TMR) - the farmer brings the livestock to maturity quickly using high-energy grains, such as maize, rather than grass. This system is analogous to commuting to work in a Formula One racing car. Sure, you might get there faster, but it takes a lot of high quality fuel to get there. Thus, for cars, as with livestock, it is far more efficient to have a car that requires less input.

This TMR system was, "the gold standard," said Dr. Michael Lee, Reader in Sustainable Livestock and Food Security. "The question is, can you pick it up and drop it in China or India? We don't think it's possible. It's about the right animals in the right system."

Increasing sustainability and improving health benefits

Choosing the appropriate breed for the environment is a crucial tenet of the WUN collaboration. As part of the first phase of their project, the Bristol team have set up collaborations with three global farm platforms spanning three very different environments: from the tropics in India, to temperate grasslands in the UK, to arid grasslands of Western Australia. In each environment, they are looking to optimise conditions so that meat and dairy can be produced sustainably from grass and forage crops with little or no extra grain input.

Credit: Michael Lee

Vechur cows at the Indigenous Breeds Research Unit, Kerala Veterinary and Animal Science University, in Kerala State, India.

Through their work with their tropical farm partners, based in Kerala, India, Eisler and Lee have shown the importance of finding local breeds. For example, the vechur cow is the world's smallest cow and is specific to the Indian subcontinent. But what makes the vechur breed so useful is that a family without any land can have one cow, feed it on waste, and produce enough milk to feed the family. This is the optimal level of sustainability that the researchers are striving towards.

Eisler and Lee are also investigating ways to improve the health benefits of meat. Long chain omega-3 fatty acids are vital for our health and can be obtained from many marine-based oils, such as fish or algal oil, but they can also be synthesised from shorter-chained omega-3 fatty acids found in plants. Humans are extremely inefficient at converting these shorter-chained fatty acids into the crucial long-chain fatty acids, whereas grazing mammals convert them much more efficiently. These long-chain fatty acids are then made available to us when we eat animal protein and grass-fed meat provides more of these essential omegas.

However, the health benefits are not in the highly processed meats, such as sausages or bacon, which are packed full of salts, preservatives and nitrites. "It's the fundamental red meat - a slice of muscle tissue - with its beneficial haeme ions and natural levels of Omega 3s," explains Lee. "We're not talking about mince or the lower quality end products; we're talking about a product that has a very important role in the human diet. It's about producing meat of a higher quality, and we can certainly do that sustainably."

A farm on every continent

The next stage of their research is to incorporate more farms, including ones in Uruguay and Ethiopia. The team are also collaborating with US universities in the states of Wisconsin and Oklahoma, where "mixed-model" farms include rotating grazing and feeding of livestock. Future collaborations will include at least one farm on every continent with arable land.

The Cabot Institute will be hosting a public event in 2014 at the University of Bristol, which will host several global experts, providing a chance for researchers to showcase their work to a wider audience. Eisler and Lee are both deeply passionate about making tasty, sustainable, higher quality meat available to those who want it. ■

Jennifer Swanstrom

Blazing the trail to better wheat yields

Deep in the heart of the University of Bristol's experimental glasshouses Keith Edwards, Professor of Cereal Functional Genomics, is tending what he calls his "space" wheat. "Apogee" is a variety of dwarf wheat with a shorter-than-normal life cycle that has been bred to thrive in the confined area of a space capsule, and may become incredibly useful in the fight for food security.

By the year 2050 the world population is predicted to grow to 10 billion, and feeding those extra mouths is a dilemma exercising the minds of policy makers and academics alike. Using more land might seem a simple solution, but swapping rainforest for crops will only make climate change worse. Instead, we need to make the farmland we have more productive by increasing crop yields, especially wheat.

Bread of the future

Until now, one barrier to developing higher-yield wheat has been the complexity of its genome. Bread wheat has six sets of chromosomes, where humans have two, and its genome is five times bigger than our own. Now a team of scientists, which includes Bristol's Professor Edwards and Dr Gary Barker, has deciphered this complex genetic code.

"Five years ago you wouldn't have contemplated this kind of project," says Edwards, who led the Bristol team. "It was a technology change called next-generation sequencing that made it possible. Instead of sequencing one or two genes it could sequence 10 or 20 million genes in one go. Now there are machines that will do 200 to 300 million genes at a time."

"What we're doing in sequencing," explains Barker, "is working out how the words are spelled. We've gone from taking individual letters, which made no sense at all, to being able to make sentences."

Scientists from the University of Liverpool carried out the initial genome sequencing of a wheat variety called Chinese Spring. Now the Bristol team is taking those data to the next stage.

Bookmarks to higher yields

The team is tracking desirable traits, which could improve conventional wheat, by identifying molecular markers - points along the DNA that serve as a sort of bookmark. Breeders can track useful characteristics by selecting for markers in the same region of DNA. To find new markers the scientists are comparing Liverpool's sequencing of the "Chinese Spring" wheat with other varieties and playing "spot the difference". They're looking for a type of marker known as single nucleotide polymorphisms (SNPs) [see box].

"If we have the sequence of one variety versus another we can see what SNP differences there are," says Edwards. "We then can identify those that are responsible for disease resistance or for growing in drought. Breeders can then use that information to screen hundreds of thousands of lines for those that have particular SNPs that define disease resistance, or increased yield, or whatever they're interested in."

To find just one SNP can mean sifting through half a terabyte of data and separating the genes from "junk DNA". The software to do this was written by Barker, who modestly

Prof.
KEITH EDWARDS

Dr.
GARY BARKER

Credit: Keith Edwards

Over 1,000 wheat varieties being grown for high performance genotyping.

describes himself as "a computer-savvy biologist", though his biology-specific programming expertise means he more technically deserves the title of bioinformatician.

The team at Bristol are also comparing wheat to its ancestors and close relatives. One relative is a grass called Agropyron, which grows in extremely arid conditions. By locating the gene that allows Agropyron to thrive with little water it may be possible to develop drought-resistant wheat. Genes from other grasses could make wheat resistant to diseases. These improvements don't require genetic modification because the markers allow breeders to carry out a conventional cross, just with more certainty that they're combining the genetic parts they want.

All of the data generated in Bristol have been made publicly available as a condition of the grant from the Biotechnology and Biological Sciences Research Council (BBSRC). The "Cereals DB" website is now one of the most accessed websites for wheat genomics in the world and the markers are used on thousands of projects such as breeding programmes at UK facilities like KWS, Syngenta and RAGT and genomics research in Australia, the US, Canada, France and China. Bristol's markers have been adopted as industry standards. ■

Adapted from Juliet Giles' Nonesuch article "seeds of change" by Boo Lewis

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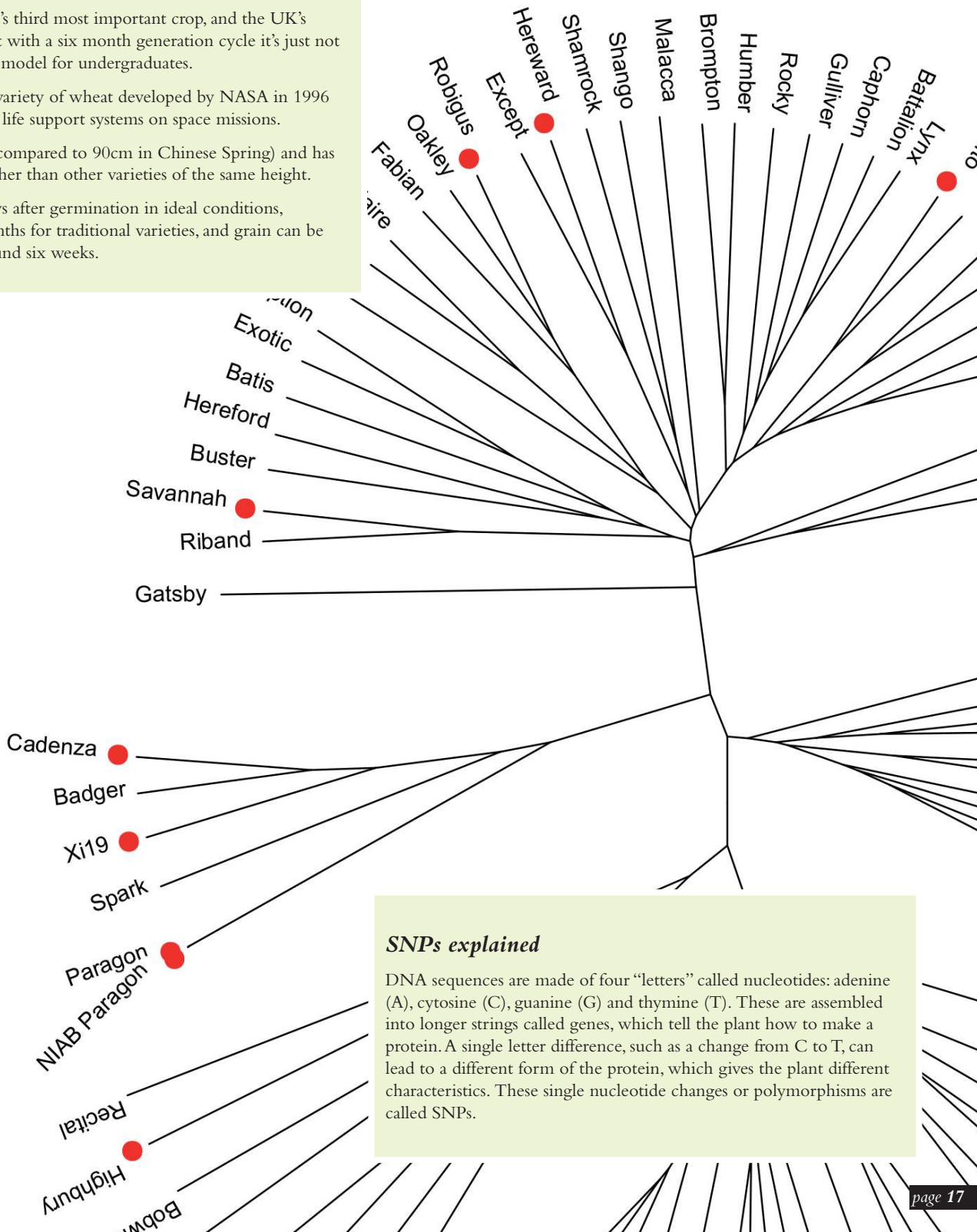
"Space wheat" facts:

- Wheat is the world's third most important crop, and the UK's premier export, but with a six month generation cycle it's just not a practical research model for undergraduates.
- Apogee is a dwarf variety of wheat developed by NASA in 1996 for bioregenerative life support systems on space missions.
- It is 45-50cm tall (compared to 90cm in Chinese Spring) and has a yield 10-30% higher than other varieties of the same height.
- Ears emerge 23 days after germination in ideal conditions, compared to 3 months for traditional varieties, and grain can be harvested after around six weeks.



SNPs explained

DNA sequences are made of four "letters" called nucleotides: adenine (A), cytosine (C), guanine (G) and thymine (T). These are assembled into longer strings called genes, which tell the plant how to make a protein. A single letter difference, such as a change from C to T, can lead to a different form of the protein, which gives the plant different characteristics. These single nucleotide changes or polymorphisms are called SNPs.

FUTURE COMMUNITIES

From environmental apocalypse to techno-centric smart cities - what are all the possible futures for our communities? These articles explore how we think about these possible futures, the assumptions that underlie them, and the actions people are taking to make them a reality.

Co-designing our futures

Keri Facer is Professor of Educational and Social Futures in the University of Bristol's Graduate School of Education. Her research interests focus on understanding the institutions, tools and forms of thought that might be developed to help us better understand and equitably navigate the rapidly changing conditions of the 21st century.

She talks to Cabot Institute Manager, ***Philippa Bayley.***

Q. ***We often talk about "the future" as though we know what it is going to be, but you talk about "futures". Why is that so important?***

"Futures" emphasises the fact that "the future" is not set in stone, that there is no single inevitable future that we are marching towards - good or bad. Using the idea of "futures" encourages us to consider that any account of the future is partial, limited and based on a whole set of assumptions and values - it is one possible future amongst many. It pushes us to ask which idea of the future is this and what underpins this idea? This starts to trigger important questions, such as, "How might this idea of the future be otherwise? What would disrupt it or throw it off-course? Could we imagine something significantly better, or worse? And what would make that happen?"

So - it matters to think in the plural - not because there are a set of predetermined futures laid out for us to choose from, but because by doing this we unsettle unexamined assumptions and open up spaces for us to think creatively and imaginatively about alternative spaces of possibility in the present.

Q. ***Dealing with uncertainty is central to the work of the Institute, but we're often talking about scientific uncertainty and how that affects decision-making. How does uncertainty play into futures thinking?***

To digress a little - I'm not sure there is such a thing as "futures thinking". Anticipation (thinking about the future) underpins a huge amount of human and animal activity, so I'm not sure we can reify "futures thinking" to its own category. However, people who have spent time working on "how to research the future", would probably respond by saying that one of our biggest problems is that we treat uncertainty as an aberration, yet in many ways it is our normality. Therefore, the challenge is to work out how to live well and intelligently with uncertainty as normal rather than seeking to eradicate it.

We also tend to mix up ideas around certainty/uncertainty and agency. Knowledge and action are not the same. We can and should act because we think something is important or good and because it underpins a future we want to create - we don't need to search constantly for forecasts and predictions in order to justify action. We need to disentangle the two issues. There are some resources on **edfuturesresearch.org** that expand on this a little more.

Q. ***Why do you think it's so important to put questions of environmental concern at the centre of futures thinking?***

Ideas of the future, at least in the West, are often dominated by technological dreams or economic projections that are premised upon a whole set of assumptions. One thing these assumptions overlook is the underlying materiality of existence - whether this concerns issues relating to environment or to human bodies. So, while I wouldn't say that environmental concern should seek to be at the centre (I don't think anything can claim that position), I'd say that we need to get better at telling more multifaceted stories about our possible futures that take in everything from the underlying eco-systems to changing bodies, aging and other forms of materiality.

Q. ***You are a "Connected Communities" Leadership fellow. What does that mean for your research and the way you work?***

The Connected Communities programme (www.connected-communities.org) now has over 280 projects across the UK and brings together communities and academics to co-design research projects around issues of shared concern. It's beginning to show us how we can connect up the everyday, practical and professional knowledge of communities with the more theoretically informed, abstract knowledge of universities to create powerful ideas for addressing contemporary challenges. Bringing together these different sorts of knowledge also opens up a creative space for not only thinking about possible futures but acting together to create them. I think it's the beginning of an exciting development change in mainstream research culture.

Q. ***How is such an engaged research approach important when we think about future cities and communities?***

There's a great phrase - chronological imperialism - can't remember who coined it, but it captures perfectly the way in which certain ideas of the future can effectively colonise the imagination and the sense of possibility. One of the challenges we face when thinking about future cities is to not let our ideas be led solely by technologists and engineers, but to open ourselves up to new possibilities and new voices in imagining a future city. The advantages of engaged and collaborative research are that it actively seeks out divergent ideas about the future that challenge our assumptions; it gives rise to new possibilities for action and makes visible otherwise overlooked problems of urgent concern in the present. This can only improve our work on Future cities.

Q. ***What are the future-facing projects that inspire you? Where could we be looking for ideas of how to involve communities in co-designing our cities and other shared spaces?***

So many… but as a great starting point, I love the Worldchanging website (www.worldchanging.com) - because it takes seriously the idea that good ideas can come from citizens or scientists and that linking them up is a political as well as a technical issue.

Q. ***Finally, what do you think are some of the most important skills we need to develop to navigate the future? What are the opportunities for us?***

We need to understand how our everyday practices of anticipation inform our assumptions and ideas about possibility in the present. We need to develop a wider and more creative repertoire of forms of anticipation. We need to understand when some approaches - probabilistic forecasting, for example - are useful and when others - creative storytelling and theatre - might be more appropriate. We need to understand when something isn't a matter of seeking more information, but a matter of ethics. And we need to get better at recognising that no futures - whether of environmental apocalypse or techno-centric smart cities - are inevitable and begin to explore whether new freedoms of thought and action emerge for us from that recognition.

Photo right: Urbanisation of Dubai. Credit: NASA Earth Observatory

Future cities: engineering perspectives

Ellie Cosgrave graduated as a research engineer from the Industrial Doctorate Centre in Systems, while Katharina Burger is a PhD student in Civil Engineering – both are working on projects that may help build the systems underlying the smart cities of the future. They talk to the Cabot Institute about their projects, the interface between society and technology, and their perspectives on future cities.

ELLIE COSGRAVE

KATHARINA BURGER

Q. What is your work/project about?

Ellie: I'm looking at how information technology is changing the way we live our lives, and particularly how we manage and run our cities. Information systems offer us opportunities to manage our cities more efficiently whilst lowering our environmental impact- but we are still working out how to pay for these systems, who should run them, and what the exact social and economic benefits might be. It's a hot topic of research at the moment, called "smart cities" research.

Katharina: Water, energy and waste infrastructures in cities are interdependent systems. I study cases in which decision makers from different sectors consider the interdependencies and decide to invest in integrated systems. I want to understand why cross-sectoral business models appear financially viable in these cases.

Q. What is your interest in the society/technology interface?

Ellie: My work sits at the boundary between technologists who are developing solutions and city councils who are working out how to use them. For a long time, technologists were espousing the benefits of superfast broadband and intelligent transport systems, but they didn't understand the significant organisational and economic barriers that stood in the way of investing in these solutions.

Katharina: Business models are tools for structuring shared learning processes. They can help decision makers to put technology in context, and surface assumptions about threats and opportunities that help people reach agreement about an appropriate allocation of risks and rewards.

Q. Why do you think the society/technology interface is important?

Ellie: Technology only exists to support our human needs. You can create the most spectacular, ground-breaking piece of technology, but if it does not serve a social need then it is redundant. Technical excellence is imperative, but if we can't translate that excellence to social value then, well, what's the point?

Katharina: The design, construction and operation of integrated infrastructure is shaped by multiple actors and multiple levels of policy. Rather than thinking about isolated technological or societal barriers to change, an integrative view sees change as being emergent from shifting configurations of actors. This thinking may enable innovative business behaviours between sectors and across perceived boundaries leading to systemic learning processes rather than piecemeal solutions in urban infrastructure development.

Q. What do you think future cities/communities is about?

Ellie: "Future cities" is about understanding that cities are, and will always be, in a state of flux. We are always going to face new challenges and opportunities that will change how we live. Future cities research helps us to understand how these changes might play out. It gives us the opportunity to create the kind of future that we want to be part of, and that we want for our children and grandchildren.

Katharina: There is increasing availability of data and development of a greater understanding through open, shared information sources. These tools make the formation of public and political opinion more integrative, transparent and responsive to change. This may enable future communities to "manage to learn in order to learn to manage".

Q. Why is it important to have industry involved in research at the outset?

Ellie: We need everyone involved in shaping this debate. That includes technology companies, government, universities, SMEs, local authorities, charities, and citizens - no one party can drive the direction of our cities, or solve the big challenges in isolation. We are all going to shape our future, and we all need to be part of the discussion.

Katharina: The involvement of utility companies, the supply network, financial institutions, public authorities and societal groups at the outset of research is important to share the available knowledge, establish dialogue and trial methodologies that help make joint decisions. Collaborative learning and decision processes prepare the ground for potentially viable business models that deliver value on the basis of mutual dependencies and interactions.

Society in the Anthropocene: figures of a future politics

The framing of the Anthropocene – the age where human activity is the dominant force shaping the environment - has so far been dominated by the physical and life sciences, especially geology. The 2013 IPCC report on the scientific basis of climate change underscores the centrality of the sciences in understanding man's relationship to the planet. Yet this concept significantly challenges the boundaries between the social and natural. What does it mean to write human agency directly into the dynamics of change in the natural world? Does this alter underlying assumptions about the relationship between nature and society, the role of rational human agency, the nature of social relations in particular physical settings, or how we respond politically to the challenges emerging from the Anthropocene?

The Cabot Institute held an international conference – Society in the Anthropocene – to explore these and other issues.

The conference brought socio-legal, political, sociological, anthropological and geographical perspectives to four thematic sessions on Carbon Politics, Urban Resilience and Global Containment, Global Environmental Uncertainty, and Capitalism, Biotechnology and the Biosphere. With social scientists getting together for the first time to tackle some of these issues, there was as much discussion about clarifying the questions as about providing answers. The Anthropocene has not yet been formally defined as a geological period in the earth sciences community, and there is no more agreement among social scientists. But certain questions consistently reared their heads: How do we think about political agency in the Anthropocene? How important is capitalism or neoliberalism? Is the notion of the Anthropocene self-absorbed and anthropocentric despite itself?

Figuring across disciplines

Human beings are clearly at least one of the dominant forces shaping the biosphere, but what is the value of framing this as an "age"? Indeed, there is a tendency to see social change in terms of epochs, but terms such as postmodernity, hypermodernity and transmodernity are all characterised by multiple strands of constant change. It was therefore striking that what might be called "figures" of different kinds haunted the papers and discussions. These ranged from figures of the body politic (the household, ethical spaces, political economy, and the democratic people) to geology (fire and land) to chemistry and physics (air and measured impact) to techno-biological bodies (toxic bodies, the pristine foetus, the remotely monitored client of humanitarian aid).

Political agency

Interestingly, while many of these figures evoked above (the body, fire, land, air) are easily imaginable as objects of (natural) scientific enquiry, there was a strong sense in the conference of the limits of science itself. Poetics and narrative were repeatedly invoked across the conference as sites or spaces that might better capture the contours of the terrain of an Anthropocene age. And despite the title of the conference, political agency rather than social relations were arguably much more central. If human action can mitigate or even reverse some of the most damaging effects of anthropocenic change, what are the new forms of political community and social relations that would be necessary? Novel uses of technology and approaches to reducing energy consumption and encouraging recycling at the local level could engender positive change in the way in which individual families and communities understood their relationship with and impact on the environment. But the sometimes apocalyptic narrative of climate change and the reliance on technical interventions to fix it may serve to de-politicise the issue. This in turn deflects attention from the political and social change necessary to transform the political economies of consumption that underpin the catastrophe in the first place. Mirroring the contemporary public discourse, a distinction emerged between those who saw positive change as being possible within broadly existing global structures and those who called for a new kind of politics that would transform global politics from the bottom up.

Beyond the human?

Finally, an abiding paradox was the question of whether the notion of the Anthropocene de-centred or actually re-centred humans. When geological time is recast quite literally using the language of human impact, are humans re-centred or refigured as a meddling pin-prick on the edge of vast natural forces, which will certainly outlast us and which may (once again?) induce respect, awe or humility rather than the urge to mastery.

Papers from the conference will be published in Economy and Society. Further information on the conference is available at: **bris.ac.uk/cabot/events/2013/206.html.** ■

Adapted from an article by Professor Bronwen Morgan (School of Law) and Professor Tim Edmunds (School of Sociology, Politics and International Studies)

Prof. **BRONWEN MORGAN**

Prof. **TIM EDMUNDS**

Credit: David Iliff. License: CC-BY-SA 3.0

GUIDING THE INSTITUTE

Credit Martin Chainey

Professors Sir John Beddington and Professor Sir Eric Thomas,Vice Chancellor

As the UK Government's Chief Scientific Adviser, it was quite normal for Professor Sir John to discuss a number of pressing global issues - from pandemics to food production - before contemplating UK flood risk over lunch. During Sir John's five years as Chief Scientific Adviser, he experienced the largest nuclear disaster since Chernobyl (Fukushima Daiichi, March 2011), volcanic eruptions in Iceland that closed European airspace, and a Swine Flu pandemic. The job had its challenges. So, when I asked him what's on his agenda now that he's left the Cabinet Office, it's not terribly surprising that he automatically defaulted to discussing the wider political landscape rather than what he has scheduled between noon and 1pm.

"I think the next decade or two are going to be really interesting," said Sir John, "because things are going to happen in this world irrespective of what we think about them. There will be another billion people, there will be more people living in cities than ever before, and there will be a rise in the middle class - all of which puts a greater demand on resources - and then there is climate change."

These are the problems that Sir John is very passionate about and having sat at the interface between science and policy for years, he knows that it is evidence rather than assertions that will help solve these problems - policies that are based on the best science possible at the time.

"One of the reasons that I'm happy to act as an adviser for the Cabot Institute," said Sir John, "is that I think the researchers here are addressing many of these key medium time scale issues."

Looking at a somewhat longer timescale - the next 50-60 years - Sir John stresses that the key is to focus on the risks that lie ahead. He rattles off a list of possible events, including pandemics, volcanic eruptions, agricultural productivity, flooding and drought; all things on the National Risk Register, which are becoming increasingly likely and increasingly severe due to global climate change.

Government needs to be thinking about whether they need to invest in mitigation for a high probability, high impact event, such as the next pandemic. "I like to reverse the calculation," said Sir John, "and say 'what are the chances of having five years without it happening?'" Then a smile crossed his face and he quickly followed with, "What are the chances of my successor being in the job for five years without one of these things happening? I think it's small."

"Again, these are issues that the Cabot Institute is working on."

Sir John knows this first hand. In 2010, during the volcanic eruptions in Iceland, he invited three volcanologists from Bristol, Dr Matt Watson and Professors Willy Aspinall and Steve Sparks to sit on the Scientific Advisory Group in Emergencies (SAGE).

He has only been in his role with the Institute since May 2013, but he has met with a number of groups already. "I like the idea that Cabot started from a bottom-up approach with a focus on these issues. But also, these issues can't be dealt with by single discipline work. It has got to fundamentally be interdisciplinary and that's one of the attractions for me to be working with Cabot."

Sir John is looking forward to being able to influence and advance the science that falls within the Cabot Institute, which is so fundamentally relevant to the policy needed to respond to these global challenges. ■

Nicola Temple

"We are honoured and excited that Sir John has joined the Cabot Institute as Chair of our Advisory Board. He brings a wealth of experience as both a practising scientist and leading policy advisor. His appointment underlines our ambition to put societal needs at the heart of our research."

Rich Pancost

Members of the Cabot Institute Advisory Board

- (Chair) Professor Sir John Beddington, *former Chief Scientific Adviser to the UK Government*
- Professor Patricia Broadfoot, *Chair of Universities UK/Guild HE Sustainable Development Task Group, Social Science Expert Panel for Defra and DECC*
- Mr Matthew Carter, *Humanitarian Director of CAFOD*
- Professor Robert Edwards, *Chief Scientist of Food and Environment Research Agency (Fera)*
- Mr Matthew Foote, *Head of Exposure and Catastrophe Management at Mitsui Sumitomo Insurance*
- Dr Andrew Garrad, *Managing Director at Garrad-Hassan*
- Professor Brian Golding, *Met Office Research Fellow in Weather Impacts*
- Mr Roy Griffins, *Chairman of London City Airport*
- Mr Will Hutton, *Principal of Hertford College at University of Oxford, journalist and writer*
- Mr Merlin Hyman, *Chief Executive at Regen SW*
- Mrs Karen Morgan, *Chairman of Trustees, The Converging World*
- Dr Robert Muir-Wood, *Chief Research Officer at Risk Management Solutions*
- Dr Paul Rainger, *Head of Sustainable Bristol City-Region Programme at Forum for the Future*
- Sir Crispin Tickell, *British diplomat, environmentalist, and academic*
- Dr Gilbert Brunet, *Deputy Director of Weather Science, Met Office*

The Cabot Institute's Artist in Residence, Neville Gabie, worked with Cultural Geographer Merle Patchett to install a series of art works in the Geology Collection basement stores to archive the ways in which oil permeates and sediments itself within our research and wider worlds. This included a premiere of a series of short films, including the one featured in this image, which Neville created in response to the experimental scientific work of Cabot Institute researchers. Find out more at **bristol.ac.uk/cabot/people/air**

Contact us

For general enquiries, or to receive weekly emails with our news, events and funding opportunities, please email
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