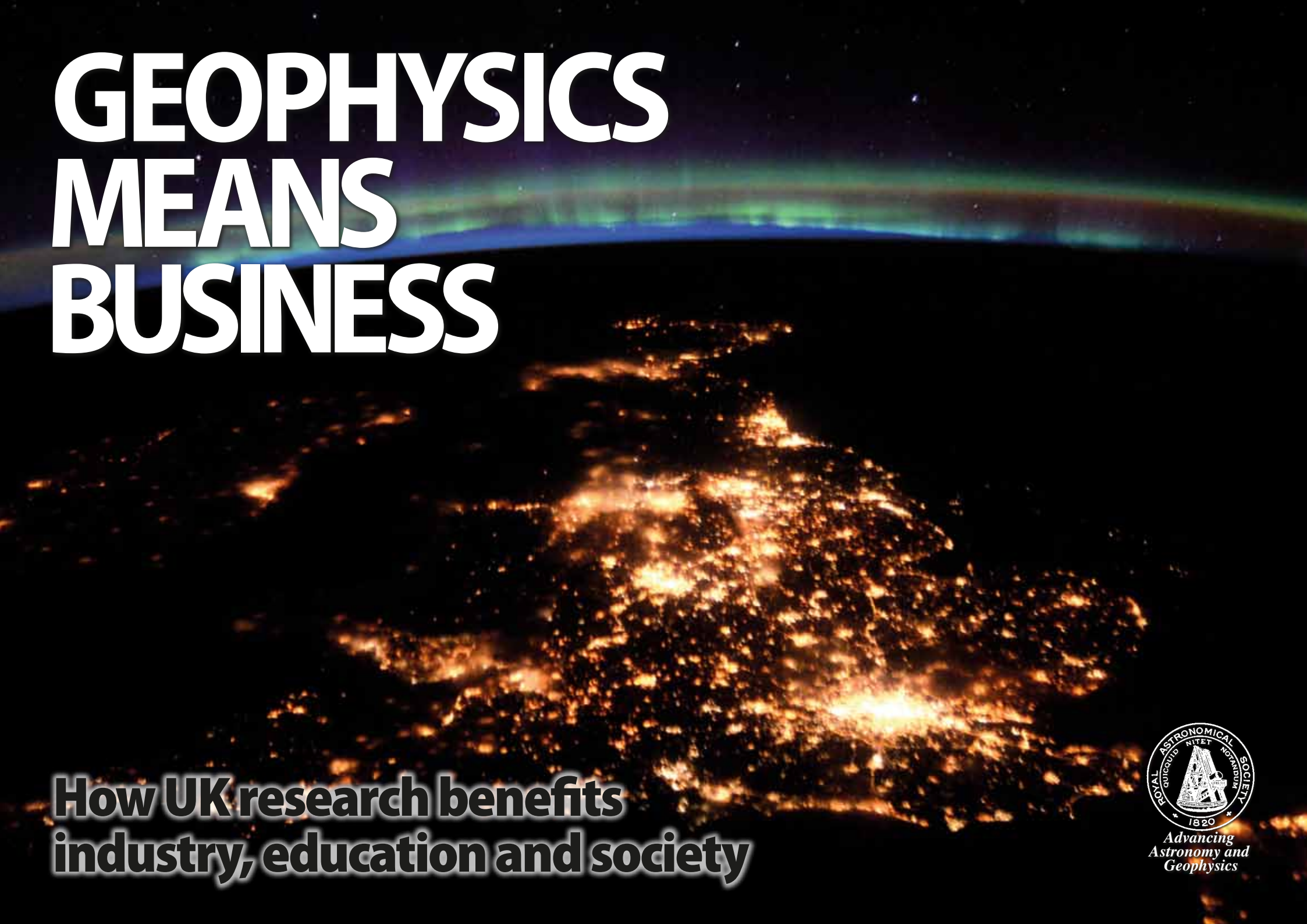

GEOPHYSICS MEANS BUSINESS

How UK research benefits industry, education and society

Advancing Astronomy and Geophysics

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GEOPHYSICS MEANS BUSINESS

This booklet was produced by the Royal Astronomical Society
www.ras.org.uk

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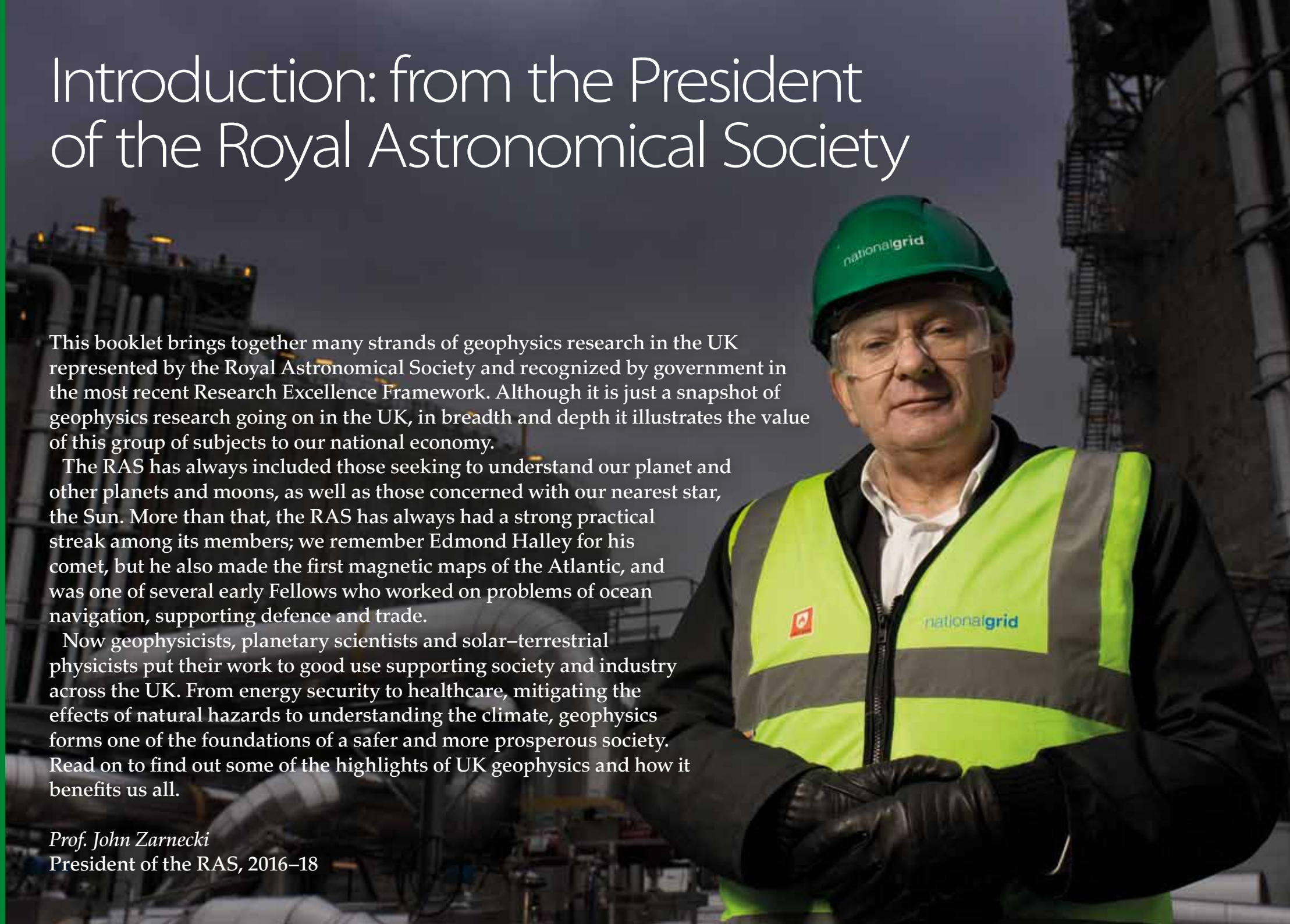
Introduction: from the President of the Royal Astronomical Society



This booklet brings together many strands of geophysics research in the UK represented by the Royal Astronomical Society and recognized by government in the most recent Research Excellence Framework. Although it is just a snapshot of geophysics research going on in the UK, in breadth and depth it illustrates the value of this group of subjects to our national economy.

The RAS has always included those seeking to understand our planet and other planets and moons, as well as those concerned with our nearest star, the Sun. More than that, the RAS has always had a strong practical streak among its members; we remember Edmond Halley for his comet, but he also made the first magnetic maps of the Atlantic, and was one of several early Fellows who worked on problems of ocean navigation, supporting defence and trade.

Now geophysicists, planetary scientists and solar–terrestrial physicists put their work to good use supporting society and industry across the UK. From energy security to healthcare, mitigating the effects of natural hazards to understanding the climate, geophysics forms one of the foundations of a safer and more prosperous society. Read on to find out some of the highlights of UK geophysics and how it benefits us all.

Prof. John Zarnecki
President of the RAS, 2016–18

An informed society

A better, wider understanding of the weather, climate and our space environment supports informed decision-making at all levels.

FORECASTING SPACE WEATHER

We live within our Sun's influence: solar flares and eruptions can bring problems for people on Earth, from disrupted satellite communications to power-supply problems. Geophysics helps us to understand how these space-weather events reach Earth and how they affect us. Researchers at University College London's Mullard Space Science Laboratory have provided tailored information about solar physics research and space weather to the insurance industry.

Aurorawatch, a free service that provides alerts when aurora are likely to be widely visible, has built up well over 100 000 subscribers. Users are encouraged to share their photographs of aurora, further widening the public impact of this natural phenomenon. Aurorawatch scientists speak and broadcast about the science of space weather, further supporting public interest. aurorawatch.lancs.ac.uk

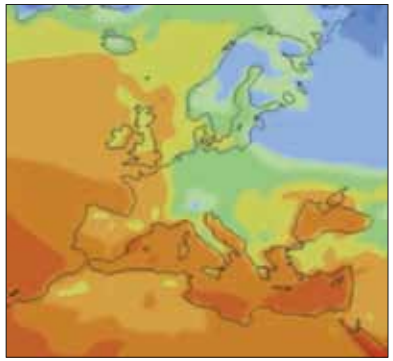
UNDERSTANDING OUR CLIMATE

The world is warming and scientists are working to understand the factors behind the rise in global temperatures. Sea-surface temperature is a key indicator of global warming; researchers at the University of Leicester have been instrumental in designing sensors for satellite measurements through the Along-Track Scanning Radiometers (ATSRs), a series of thermal infrared sensors on European satellites including Envisat.

The temperature record provided from orbit provides a record independent of that from weather stations on the ground; work at Leicester has established that it is accurate to a fraction of a degree. The data are part of the International Panel on Climate Change (IPCC) database and are an important part of the scientific basis used for UK government climate policy. The data are also sufficiently accurate to be useful for ocean-weather forecasting at the Met Office and the European Centre for Medium Term Weather Forecasting.

▼ **Lights in the sky**. Aurora, here shown over Stirling, can be a sign of damaging space weather.

GETTING INVOLVED



More than a quarter of a million citizen scientists have taken part in an experiment to determine the uncertainty associated with climate prediction. Researchers from the University of Oxford, the Open University, the Rutherford Appleton Laboratory and the Met Office used volunteers' computers to run one climate model many times, to find out how much the predicted outcomes differed. The project – climateprediction.net – produced the first probabilistic forecast of global warming arising from human activity, without the high computing costs usually associated with this approach. The project also generated considerable interest from the public worldwide, giving volunteers insight into climate modelling.

climateprediction.net

CRUNCHING CLIMATE NUMBERS

Climate data inform our response to global warming. Researchers at the University of Oxford have quantified the role of cumulative carbon emissions – rather than current greenhouse gas concentration in the atmosphere – in driving a political strategy. This approach has been used by the IPCC, in advice to government and locally. Shell used this approach in support of its investment in carbon capture and storage technology.

CLIMATE AND GEOENGINEERING

Researchers from the Natural Environment Research Council National Oceanography Centre at the University of Southampton developed climate modelling programmes that included novel interactions between ocean and atmosphere as well as the effect of land and ice sheets. These GENIE climate models can run for up to a million years, and show enough detail to shed light on regional climates. GENIE can also assess the statistical significance of key outcomes. Southampton researchers also assessed the potential of geoengineering: large-scale projects to alter the Earth's climate in ways that would mitigate the effects of climate change. They highlighted both good and bad effects of such projects.

INDUSTRY FOCUS

SEEING STORMS, SAVING MONEY

Sea-surface temperature is one of the factors influencing the severity of tropical storms; researchers at University College London provide real-time alerts of tropical storms worldwide based on their research, under the name Tropical Storm Risk (TSR). Lord Leven, the chairman of Lloyd's, stated: "TSR is the first to offer a level of precision that is of practical use." The service was selected to provide alerts to Reuters AlertNet, the global humanitarian alert service. It also supports the reinsurance industry with alerts and information on extreme weather worldwide.

TSR also provides alerts for extreme weather in Europe, especially windstorms, which account for three-quarters of insured losses arising from weather. Together, these alert services generated £1.319 million from commercial sales over the period 2009–2013.

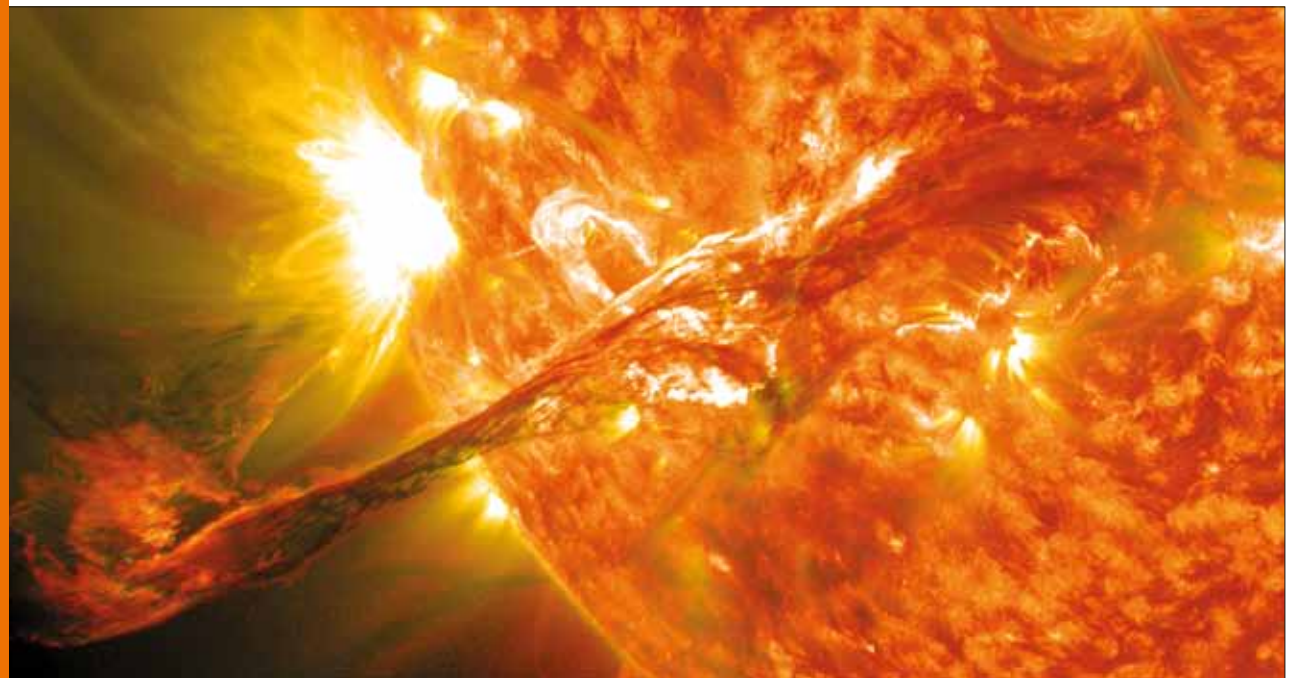
tropicalstormrisk.com

▶ **Storm alert**. Warnings of the expected severity of tropical storms such as Beryl mitigate the risks they pose to lives and livelihoods.

Global education

Solar physics, space weather and planetary science draw young people into science and technology careers.

▼ **Sun storm**. Eruptions of matter and energy from the Sun bring us spectacular aurorae as well as disruption to technology such as satellite navigation and power grids.



SPACE WEATHER IN SCHOOLS

Solar storms can compromise satellites and services such as satellite navigation; electrical power infrastructure is also at risk. British Geological Survey staff have developed a magnetometer for schools, giving pupils hands-on experience of coding as well as space-weather detection. The project follows a similar programme to supply seismometers to schools.

The British Geological Survey also alerts the public and industry to solar storms, and provides data to the Aurorawatch alert system, developed by researchers at the University of Lancaster.

bgs.ac.uk

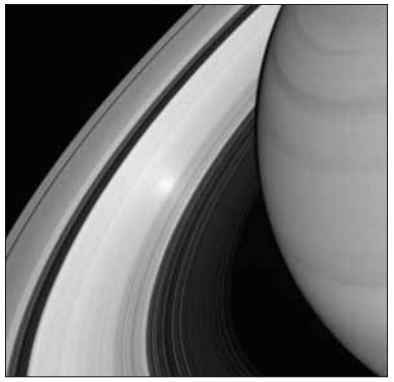
HOW THE SUN WORKS

Researchers from University College London's Mullard Space Science Laboratory have been describing how the Sun works at public and school events, as well as supporting teachers with training and teaching resources.

Scientists from the University of Cambridge have set up Sun|Trek, a dedicated website about solar physics that presents images and information about the Sun's behaviour in an accessible form for the public in general and young people in particular.

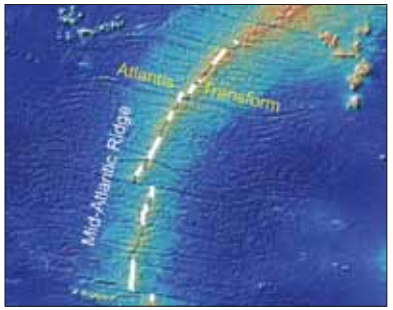
suntrek.org

PLANNING FOR THE PLANETS



Queen Mary University of London offered schoolchildren the opportunity to be mission planners for a day on the Cassini mission to Saturn. This teamwork exercise required scientific thinking and constructive argument, as teams of mission planners sought to develop the best observing sequence, using a model of the ESA/NASA spacecraft Cassini, as it explored Saturn and its moons. This activity was part of the Media Space programme, run in partnership with two education charities: the Ideas Foundation and Venture Thinking. The project evolved into Cosmic Futures, a writing competition in partnership with the *Metro* newspaper, which has a readership of more than a million.

ALL AT SEA



UK expertise in marine geophysics was shared with schools through the Teacher at Sea project, in which teacher Angela Bentley joined and taught from a research expedition to the Mid-Atlantic Ridge aboard the RRS *James Cook*. The project was funded by the Natural Environment Research Council and supported by researchers from the universities of Birmingham, Cardiff, Durham and the National Oceanography Centre at Southampton.

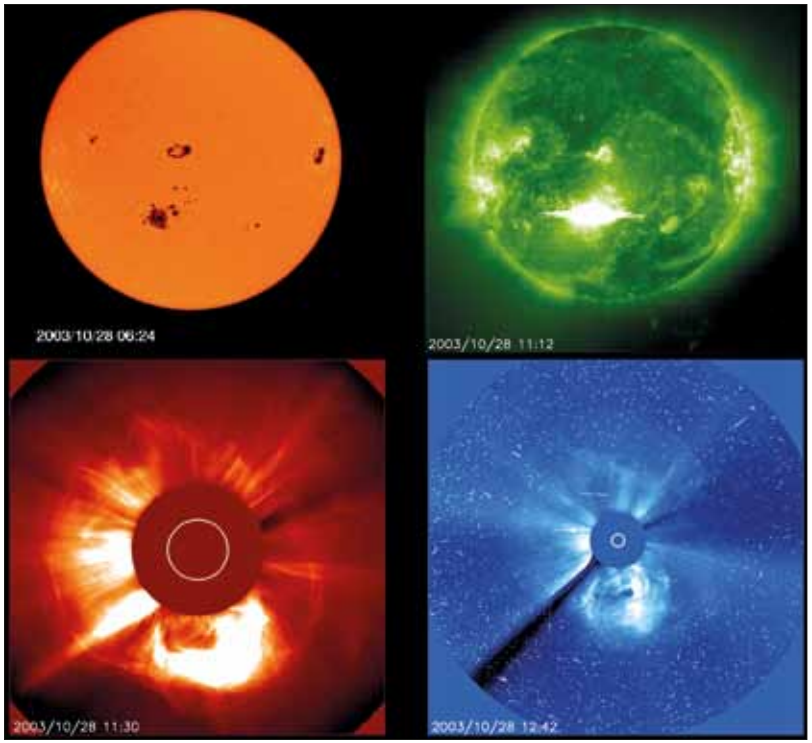
WELSH CULTURE MEETS THE SOLAR SYSTEM

Researchers at Aberystwyth have been presenting information about solar and planetary physics to a wide audience at the Welsh cultural festival the Eisteddfod and the youth festival, the Urth Eisteddfod. The team has also engaged with visitors through art installations and dance.

Healthy and safe

Complex monitoring and decision-making is part of geophysics in our environment – and in intensive care.

INTENSIVE CARE FROM SOLAR PHYSICS



▶ **Sun spotting**. Combining different forms of solar data – at a range of wavelengths and scales – to show what precedes a giant solar eruption provides a means to forecast medical emergencies for patients in intensive care.

When many different monitors track the condition of acutely ill patients, it can be difficult to pick out changes that threaten a patient's life. But dangerous combinations of symptoms can be identified automatically, using expertise developed in solar physics.

Tracking what triggers flares and eruptions on the Sun demands constant monitoring of different measures of the Sun's activity. Solar physicists have developed software to identify key changes taking place together in several streams of data that presage an eruption. Now, in combination with medical specialists, scientists from University College London are applying similar technology to pick out danger signs in acutely ill patients. The goal is an automated system that alerts medical staff quickly to signs of deterioration.

WATCHING THE WASTE

Radioactive material can be a public hazard, whether it comes from nuclear waste, nuclear accidents or potential terrorism. A team from the University of Glasgow has been working on how radioactive materials such as carbon-14 accumulate and move on and in the sea. They have developed new methods of picking out sources of the highest risk, including portable gamma-ray spectroscopy instruments that can survey from the air on drones. With Japanese researchers they developed a backpack detector in the wake of the 2011 Fukushima nuclear accident. Their work is also useful for understanding how underground repositories for nuclear waste may work in the event of future climate change, and for assessing the behaviour of depleted uranium released from armour-piercing munitions.

BREATHE EASY

Monitoring pollution in the environment has become a priority with increased awareness of the harmful effects of gases such as nitrogen oxides. While roadside and city-wide monitors give a detailed picture, satellite data provide useful and increasingly detailed overviews. Researchers from the University of Leicester have developed better ways to extract useful information for society from satellite readings. The team has applied Bayesian statistics to assess the quality of the measurements and ensure that results are robust. Their work is important for urban air-quality data as well as greenhouse gas levels and cloudiness.

Dangerous planet

Natural hazards damage national and local prosperity – and cost lives. Geophysics research helps to anticipate hazards and mitigate their effects.

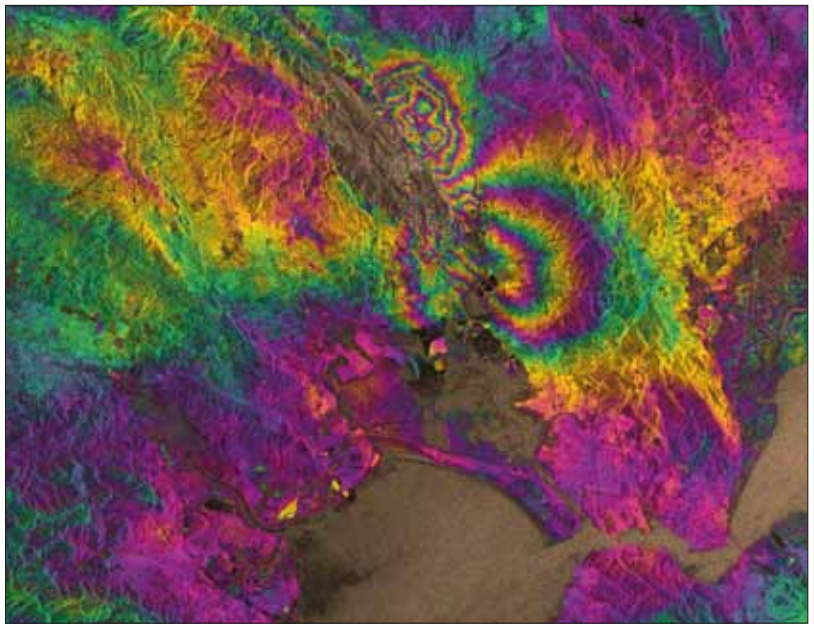
SHAKING THE SURFACE

Earthquakes are not a major hazard in the UK, but UK research helps to save lives worldwide. The UK research consortium Comet makes use of fieldwork and satellite data to understand how the earthquakes we know about fit into the long-term deformation of the Earth. The fundamental understanding developed by Comet members at the universities of Cambridge, Edinburgh, Leeds and Oxford is directly useful for refining hazard assessments in high-risk areas such as Italy and the Aegean. They also make use of the European Sentinel satellites, allowing speedy assessment of the effects of quakes.

SEISMIC HAZARD MAPPING FOR BUSINESS

Scientists at University College London and Birkbeck College have focused on better seismic hazard mapping for institutions such as banks, with a focus on building resilience. The new models have been used by the Bank of Greece, the Italian Institute for the Protection and Research of the Environment, and the Italian National Institute for Geophysics and Volcanology. The models have also formed the basis for information and training for a range of UK industry groups in the fields of engineering, insurance and investment through the Natural Environment Research Council PURE network.

▼ **Amatrice**. A series of earthquakes in central Italy has highlighted the need for a better understanding of seismic hazards and improved communication with those at risk.



TRACING TREMORS IN ITALY

Geophysicists at the University of Edinburgh are working for the Italian government to understand in more detail the rock physics processes leading to an earthquake rupture. They provided operational earthquake forecasting based on this work. They also considered statistical approaches to earthquake forecasting and issues around the communication of risk. Their work has influenced government policy in the UK, Italy, Greece, Japan and Russia.

British Geological Survey staff are also working to support Italian government scientists in understanding the seismic risk to local communities. The recent devastating earthquakes in central Italy have highlighted the difficulties inherent in assessing seismic risk and the problems of communicating that risk effectively to local and regional authorities.

▲ **Seeing with satellites**. Satellite radar measurements used by research consortium Comet quantify Earth movements.

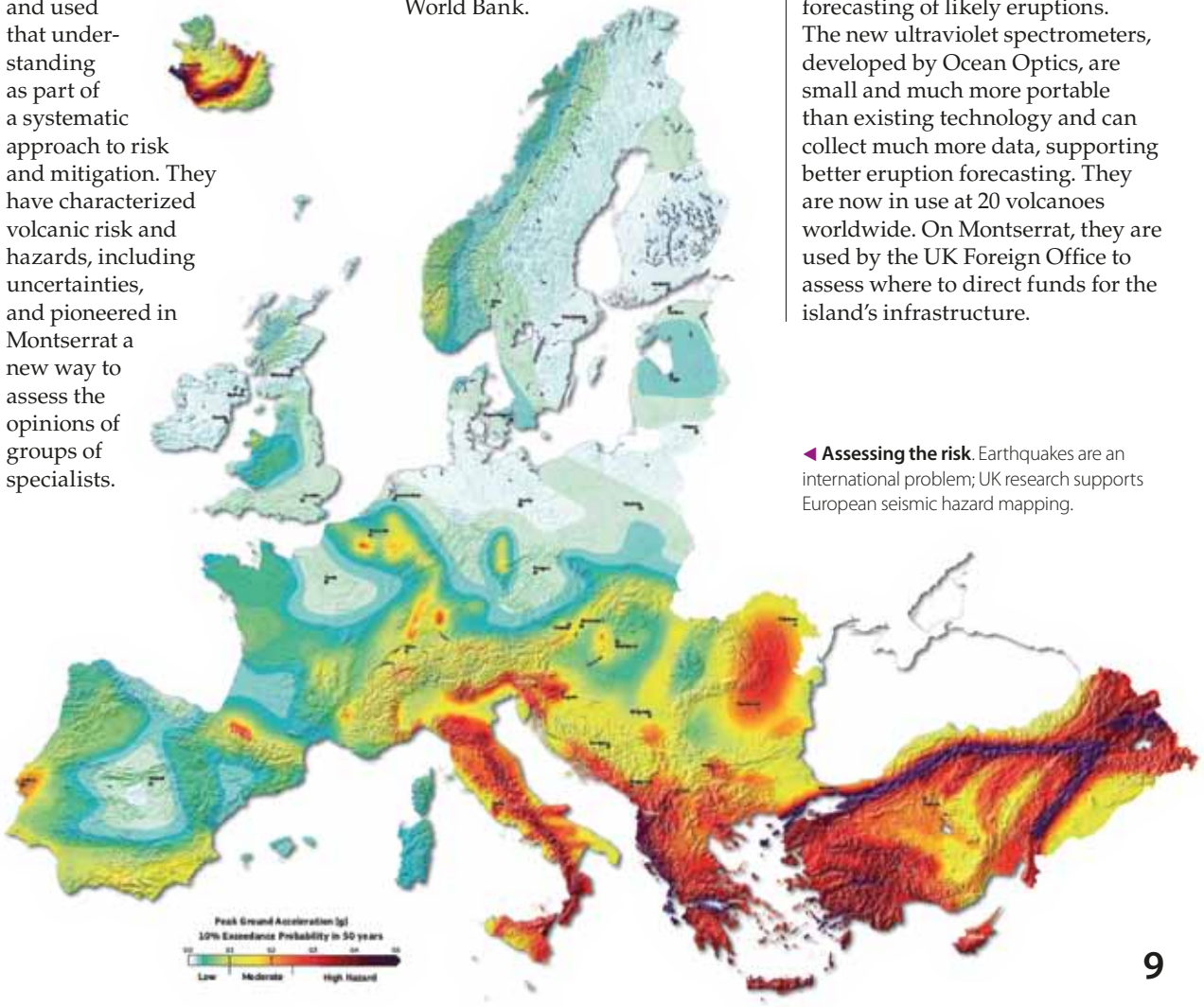
◀ **Volcano alerts**. Forecasting eruptions is notoriously difficult, but UK researchers are improving predictions using portable automated sensors.

REFINING VOLCANIC RISK

Geophysicists at the University of Bristol have combined fieldwork with numerical modelling to understand volcanic processes and used that understanding as part of a systematic approach to risk and mitigation. They have characterized volcanic risk and hazards, including uncertainties, and pioneered in Montserrat a new way to assess the opinions of groups of specialists. This approach is now used for volcanic eruptions worldwide; their work has had funding from private sector organizations such as the World Bank.

AUTOMATING ERUPTION ALERTS

University of Cambridge scientists have developed automated sensors for use at the Montserrat Volcanic Observatory, giving improved forecasting of likely eruptions. The new ultraviolet spectrometers, developed by Ocean Optics, are small and much more portable than existing technology and can collect much more data, supporting better eruption forecasting. They are now in use at 20 volcanoes worldwide. On Montserrat, they are used by the UK Foreign Office to assess where to direct funds for the island's infrastructure.



◀ **Assessing the risk**. Earthquakes are an international problem; UK research supports European seismic hazard mapping.

MANAGING URBAN WATER RESOURCES

Research at the University of Birmingham on the flow of water, pollutants and particles through aquifers has supported management of two regional aquifers serving 1.5 million people in Liverpool and Manchester. These aquifers pass beneath urban and industrial areas, known sources of pollution; the modelling identified useful groundwater resources for the future.

FORENSIC SEISMOLOGY FOR INTERNATIONAL SECURITY

Geophysicists at the University of Oxford and the Atomic Weapons Establishment at Blacknest are also involved in using seismology to monitor nuclear tests worldwide; the signals from underground tests, such as those recently carried out in North Korea, can be detected and distinguished from natural seismicity. The UK had demonstrated international leadership in forensic seismology and is home to the independent verification organization Vertic.

Parting the clouds

Volcanic ash brought European air traffic to a standstill in 2010; geophysics research helped to minimize the disruption.

BEATING THE FLIGHT BAN

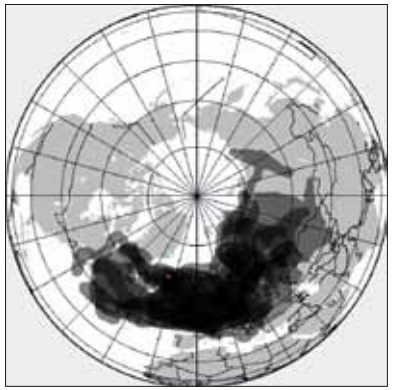
Scientists from the universities of Edinburgh, Hertfordshire and Manchester examined the ash cloud from the eruption of Eyjafjallajökul. The Edinburgh team compared the 2010 data with the history of eruptions on Iceland, supporting real-time assessment and modelling. Their work supported operational decision-making by aviation authorities and the UK and Iceland Met Offices and contributed to the relaxation of the flight ban by the UK Civil Aviation Authority.

University of Hertfordshire researchers had conceived and built instruments to measure particles in the atmosphere; these *in situ* data were some of the first to come from the ash plume, helping to validate Met Office models of the extent of the plume. The instruments were built to measure the polarization of starlight, but they also detect dust in the atmosphere. They were launched on balloons and so were able to work during the ban on airlines, providing vital data promptly.

Manchester researchers focused on the calibration of probes used to image the cloud, on better analysis of cloud data and how they could be used to determine the nature of the ash in the cloud.

▶ **Eyjafjallajökul**. Most Icelandic eruptions do not hamper air traffic, but geophysics can identify the factors that make ash a hazard.

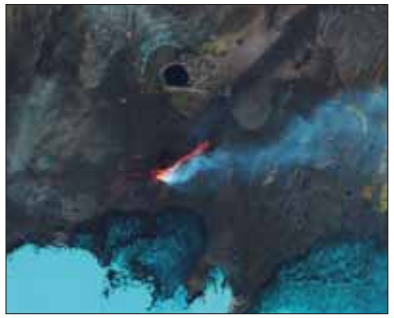
COST OF THE CLOUD



The eruption of volcano Eyjafjallajökull on Iceland in 2010 grounded air traffic in Europe for almost a week, affecting 10 million travellers. The ban cost the UK airline industry up to £130 million per day. Geophysicists provided immediate information to air traffic controllers, and have since contributed to the development of new instruments and models of ash plume formation and dispersion.

▲ **Mapping the cloud**. Maps of ash density (top left) and satellite imagery (top right) helped to assess the risk to aircraft in real time.

QUANTIFYING THE RISKS



Researchers at the University of Bristol developed new satellite instruments to refine the data on the composition of ash clouds. They advised the Civil Aviation Authority, the UK government and the European Space Agency. They also adapted methods developed in volcanic eruptions to quantify the risk to aircraft and advised aircraft-engine manufacturer Rolls Royce, influencing their corporate research and helping them to develop world-class expertise in this area.

Scientists at the University of Leeds used past eruptions to assess that there is a significant health risk from volcanic gases and ash particles from Icelandic eruptions, comparable to seasonal flu. Their model suggested a potential 100 000 deaths across Europe. Their work supported the addition of large Icelandic eruptions to the UK National Risk Register of Civil Emergencies.

Foundations of growth

The UK construction industry relies on geophysics for environmental surveying, on land and at sea.

DIGGING DEEP FOR INFRASTRUCTURE

Site investigation ahead of construction work used to be an expensive process involving boreholes, excavation and considerable – and costly – uncertainty. Geophysical methods to image the subsurface have transformed this field, reducing both costs and construction times, especially for large infrastructure projects. "When the project is of sufficient size and complexity, say the HS2 railway or a new nuclear power plant, you have to keep the risks under very tight control," says George Tuckwell of RSK (see panel, right). "When you absolutely have to get it right, use geophysics first."

SURVEYING THE SEAFLOOR

Geophysics has transformed our knowledge and management of the near-surface seafloor, important for marine cultural heritage, renewable energy infrastructure and law enforcement.

University of Southampton researchers developed non-invasive acoustic methods to image the shallow subsurface, testing them on archaeological sites such as the wreck site of the *Mary Rose*. The Southampton group boosted accuracy to 10 cm in three dimensions. Their technique has been used by English Heritage, while The Crown Estate used it to assess subsea resources including sand in the Thames Estuary.

▶ **Underground upgrade.** Modern infrastructure such as Crossrail in dense urban settings makes use of geophysical imaging for three dimensional site investigation.

INDUSTRY FOCUS

KONGSBERG GEOACOUSTICS LTD

This company, based in Great Yarmouth, is a leading manufacturer of seabed sonar survey equipment. According to its president: "The developments in 2D Chirp technology undertaken by University of Southampton and feedback from their research projects using the systems, have been integral to the ongoing development of our leading sub-bottom profiler products (c.£2 million income), while our current agreement with them to commercialize their 3D Chirp system is now coming to fruition with the first systems being delivered to clients (first sale to China in 2013). Their academic expertise in sub-bottom data processing and interpretation is world class, helping us to keep our products competitive in a truly global market and our development grounded on cutting-edge but solid science."

km.kongsberg.com/geoacoustics

RSK: BIG DATA BEAT DIGGING

Engineering geophysics is changing how we can map the ground beneath our feet, thanks to cheaper hardware and electronics. The next step is to integrate and manipulate the resulting big data sets, according to George Tuckwell of RSK Group.

Hardware and electronics costs have decreased to the point where they now offer the potential for time-lapse geophysics: real-time monitoring of changing conditions. "It might be monitoring water content and ground stiffness on an unstable slope," says Tuckwell, "in order to identify trigger points before a landslip happens, rather than just afterwards."

Tuckwell sees a bright future for the industry: RSK's geophysics team has doubled its staff numbers in the past five years and is involved in research with the University of Birmingham to develop new gravity sensors based on quantum technology, to further improve detection of subsurface hazards.

environmental-geophysics.co.uk

Space for industry

Satellite and space technology is one of UK industry's success stories; researchers also analyse the risks to the UK of space weather.

▼ **Lights in the sky**. Aurora indicate the interaction between Sun and Earth; geophysics helps to understand the process and manage the risk to technology.

SPACE WEATHER HAZARDS

Solar storms change our space environment in ways described as "space weather": the activity of the Sun affects satellites (and all the location and communication applications that rely on them), raises radiation levels for airline passengers and can endanger power supplies.

Space weather is now on the UK National Risk Register and the Met Office offers forecasts alongside the weather forecasts. Researchers at the universities of Edinburgh, Exeter, Lancaster, Leicester, Imperial College London, University College London and at the British Geological Survey work on this Sun–Earth connection and how it affects life on Earth.

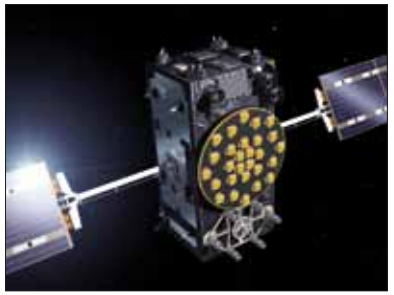
KEEPING POWER FLOWING

Space weather can affect power transmission by inducing electrical currents in power lines, railway lines and oil pipelines. Scientists from the British Geological Survey and the University of Lancaster have investigated the effects with the National Grid, finding that the geometry of power networks affects how the system responds. Their work feeds in to planning based on the National Risk Register, for example on the effect of space weather on local and regional electricity substations.

RESILIENCE FOR FINANCE

Geomagnetic storms affect the performance of global navigation satellites such as the US Global Positioning System or the European Galileo array; loss of satnav would hinder emergency services. Legal and financial systems that use these systems for timing transactions would also suffer. University College London research has identified space-weather resilience as part of business-wide planning for the financial sector, especially those companies relying on high-volume international transactions.

SPACE FOR INDUSTRY



The space industry is a driver of growth in the UK, worth £13.7 billion to the UK economy in 2014–2015 and employing close to 40 000 people. London is also a centre for satellite insurance and reinsurance, building on expertise from University College London, among others.

Designing and building instruments for space missions is a strength of researchers from University College London, the Open University and the University of Leicester. RAL Space on the Harwell Campus is a focus for satellite and instrument design, taking leading roles in major European and international projects, including Earth-observation technology.

GETTING SPACE TO SMEs

University of Leicester scientists have developed software techniques to support Earth observation, to better model the spectral signal from our planet, and to understand long-term big data sets such as those needed to assess the changing climate. Leicester researchers developed the Global Space Technology Exchange Partnership (G-STEP), to open up opportunities from space technology and high-performance computing for small and medium-sized businesses in the East Midlands. G-STEP added more than £1 million to the regional economy in its first three years, developing links with 30 local businesses new to space interests. Leicester developed links with the Satellite Applications Catapult at Harwell Campus and played a part in the industry-led Climate and Environmental Monitoring from Space Facility there.

Fuelling the economy

INDUSTRY FOCUS

A thriving economy needs energy; UK research supports a strong sustainable hydrocarbon sector, employing geophysicists and driving exploration and production.

FINDING THE FUNDAMENTALS

▶ **Drilling for oil**. An oil rig in the North Sea – just one example of where geophysics techniques are vital to show us what lies beneath the surface.

UK research has underpinned the targeted exploration of the North Sea and new hydrocarbon provinces worldwide, by UK and world hydrocarbons companies. Researchers from the universities of Aberdeen, Bristol, Birmingham, Cambridge, Durham, Leeds, London, Southampton and elsewhere are continuing this tradition, exploring the oceans and their margins.

Scientists at the University of Cambridge are developing seismic imaging methods that penetrate below the igneous rocks prevalent at continental margins, taking hydrocarbon exploration into new frontiers. Researchers at the universities of Durham and Southampton are exploring the mid-ocean ridges to understand how plate boundaries form.

This academic heritage has led to close ties between UK universities and industry. Spin-off companies such as MTEM at Edinburgh and Getech at Leeds have used research expertise in ways that benefit UK industry: MTEM has returned £5 million to research at Edinburgh, while Getech now employs more than 100 people with annual revenues of up to £8 million. In 2000, BP established the University of Cambridge BP Institute with a £25 million initial endowment, to foster fundamental research in areas important to the hydrocarbons industry.

WORKING UNDER PRESSURE

High-pressure hydrocarbons in reservoir rocks raises the risk of delays and damage during operational drilling. Researchers from the universities of Durham, Newcastle and Heriot-Watt developed techniques to map and predict areas of overpressure in different rock types in the North Sea; the spin-off company GeoPressure Technology (now Ikon Geopressure) had 20 employees (2013) and revenues of £10.8 million between 2008 and 2013. Its approach is proving valuable for safer drilling in the North Sea, offshore Canada, Norway and West Africa and supports the UK hydrocarbons production industry.

ROCK SOLID IMAGING

University of Southampton researchers have developed controlled-source electromagnetic techniques through collaboration with Statoil and ExxonMobil, resulting in two spin-off companies. One of them, Offshore Hydrocarbon Mapping, was floated on the London Stock Exchange's Alternative Investment Market in 2004 at a value of nearly £50 million. This company is now Rock Solid Images, offering electromagnetic, seismic and rock physics services to clients in the hydrocarbon industry worldwide.

Fuelling the future

The UK needs affordable, reliable energy supplies to fuel a strong economy in the coming decades. Geophysics ensures that new energy sources can be safe and effective.

SAFE FRACKING

The UK has considerable amounts of potential shale gas resources – gas held in rock formations less permeable than traditional reservoir rocks. Exploiting it requires hydraulic fracturing, a technique developed in established hydrocarbon provinces such as the North Sea. Considerable research expertise in this area, for example at the University of Leeds, supports the safe use of this technique.

But hydraulic fracturing – fracking – is a controversial process. Researchers at the University of Durham have been working to develop both public understanding of the process and good practice for the industry, and have established a protocol for safe fracking decision-making.

▶ **Testing, testing**. Shale gas may bolster UK energy reserves in the future, but fracking cannot go ahead without trusted and stringent regulation, together with informed consent from local communities.

INDEPENDENT OVERSIGHT

Fracking is a controversial process and all involved – government, industry, communities – need to understand its environmental impact. The British Geological Survey (BGS) provides independent oversight as part of its environmental monitoring, for example of the natural level of earthquakes and methane present in groundwater. BGS research in Lancashire and Yorkshire is already delivering integrated environmental monitoring, with the results publically available. A £1.7 million government-funded project provides independent data, thus providing a framework for the future.

The BGS is also leading a research team to develop a seismic monitoring system that will ensure that the effect of fracking in the UK can be monitored. The BGS has also collated and examined existing coal and oil industry borehole data in order to understand rock stability in UK stress conditions and understand how fracking may affect key rock formations.

TRACKING THE AQUIFERS

Part of the risk assessment needed in areas where hydraulic fracturing to release shale gas is under consideration is the possibility of contamination of water supplies. The British Geological Survey is mapping the separation of potentially productive shales from the major aquifers across the UK, which, in combination with measurement of methane naturally present in groundwater across the country, is providing valuable information about the potential environmental impact of fracking.

SMALL QUAKES, BIG BUSINESS

Microseismicity is an important source of information about the subsurface. Researchers at the universities of Bristol and Leeds are using it to understand fluid flow underground, in order to understand the effects of fracking to exploit shale gas.

Scientists at the University of Keele are examining how microseismicity can be used to monitor fluid flow around potential nuclear waste repositories, as well as being a useful safety marker for mine workings. They are also investigating how to monitor microseismicity transmitted to the bedrock on which large wind turbines stand.

EXTRACTING EVERY LAST DROP

Researchers from the universities of Bristol and Leeds have worked with the oil and gas industry to understand microseismicity developed when oil and gas are pumped out of reservoir rocks. The rocks change shape and generate tiny earthquakes, too small to cause damage but big enough to track how the stresses in the rock alter and affect the flow. The research streamlines hydrocarbon production. Their work is especially useful in reservoirs at the ends of their lives, maximizing the return on the infrastructure investment for UK industry. The project has led to the formation of Rockfield Software Ltd, whose models are used across the oil and gas industry to predict reservoir behaviour, generating more than £500 000 per year in sales.

CAPTURE AT SOURCE

Scientists at the universities of Edinburgh and Cambridge have been working with industry partners to evaluate carbon capture and storage systems. The University of Edinburgh has reviewed potential UK sites for carbon capture and storage and has provided assessments of likely geological repositories in the North Sea. University of Cambridge researchers, working with Shell Global Solutions BV, have looked at the potential long-term behaviour of carbon dioxide in storage by examining how and by how much natural reservoirs leak. Researchers at the University of Bristol have developed software to analyse tiny earthquakes in the reservoir rocks, which indicate fracturing and potential leaks, using arrays of seafloor seismometers.

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