Met Office

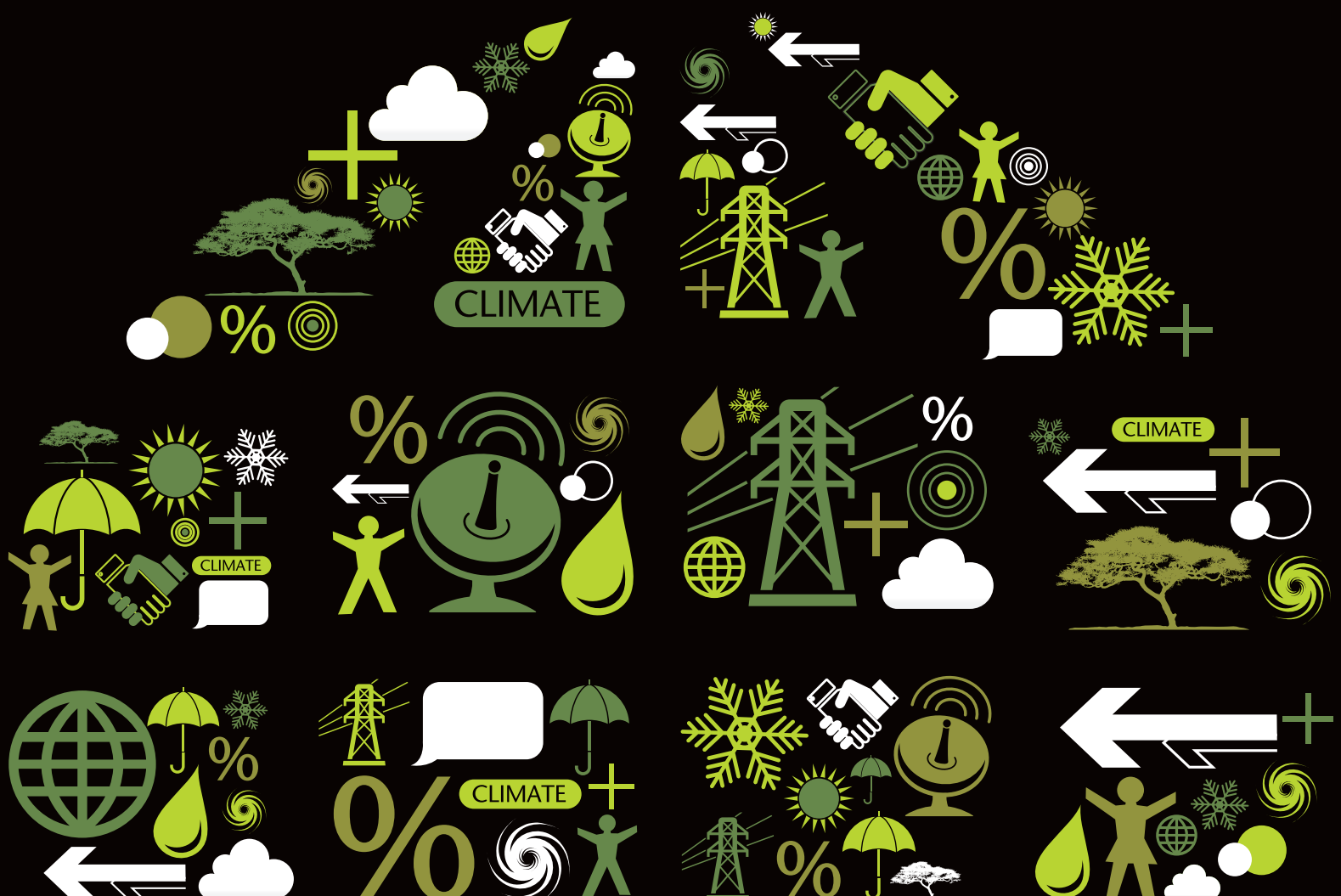
Global challenges
Making science relevant

Defining partnerships
Not just forecasting

Changeable seasons
The value of verification

Barometer

Issue 24 www.metoffice.gov.uk Met Office magazine



John Hirst, Met Office Chief Executive, discusses the significance of our work on the world.

Global challenges, global consequences

In the last 14 months the country has gone from drought early in 2012 to an exceptionally wet summer giving us the second wettest year in the UK national record. These extremes were followed by a long and cold winter.

With the coldest spring in 50 years at the start of 2013, the weather continues to break records (see page 5). The same is true around the world. At the time of writing there have been severe storms and tornadoes that have struck the US. Meanwhile, many countries across Central Europe suffered heavy floodwaters and swollen rivers.

Weather and climate, which in some people's minds are separate entities, are in fact two sides of the same coin. At the Met Office we have experts working across all forecasting timescales. In this issue of Barometer you can read articles that describe how we provide forecasts spanning different timeframes, some of them on a world scale.

I'm particularly proud of the way the Met Office translates leading-edge science in to practical services and advice for our customers. We work with partners to capture the benefits of UK science to the advantage of UK government, business and citizens, and the world at large. On page 10, Director of Science, Andy Brown and Chief Information Officer, Charlie Ewen, explain the role of technology in translating pure science to create relevant products and services for customers.

Society's increasing vulnerability and exposure to climate-related hazards are highlighted by the weather in 2012. Building on our knowledge of climate science, Climate Service UK marks a step-change in providing services to gauge how a changing climate might affect society. With the right climate information and tools, specialist services and expert advice, we will enable shrewd decisions to be made by governments and businesses that address the risks and opportunities brought about by our changing climate. Crucially, Climate Service UK is expected to deliver services all around the world (see page 7).

Meanwhile, at home, the Natural Hazards Partnership (NHP) is pulling forward short-term predictions for use in early warnings about extreme weather and other natural hazards. The European Commission recently endorsed the work of the NHP, as highlighted on page 17.

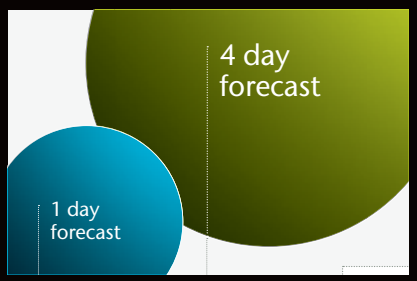
We don't just forecast the weather. Weather determines what we do, how we dress and what we eat. The impacts of climate change on global food availability are one of the biggest challenges the world faces. Food security planning decisions must be based on the available evidence. Working together with the World Food Programme we examined some of the issues surrounding climate change and food security (see page 21). Again, this highlights the importance of our work to people, and leaders, the world over.

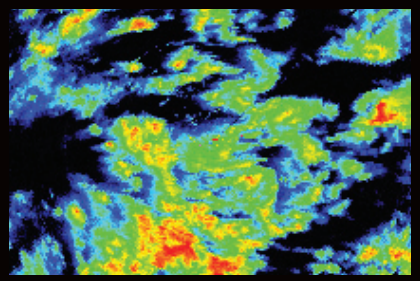
Many of the weather and climate challenges we face are global in scale and consequence. Providing information and tools to enable the UK and wider world to cope is vitally important, so we work to address the task every day.

Barometer is also available online at www.metoffice.gov.uk/barometer

This _Barometer_ is a review of the year. To find out more about our work, see this year's Annual Report at www.metoffice.gov.uk/publications.

In this issue





News and updates

Features

People

Science

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Meeting on UK's run of unusual seasons

Experts from across the UK met at the Met Office in June to discuss the run of unusual seasons in Europe. Representatives from the Universities of Exeter, Leeds, Oxford, Reading and Imperial College London, as well as the Met Office looked at the weather patterns and their potential causes in three recent seasons – the cold winter of 2010/11, the wet summer of 2012, and this year's cold spring.

Professor Stephen Belcher, Head of the Met Office Hadley Centre said: "Ultimately what we've seen in each of these seasons is shifts in the position of the jet stream which impact our weather in certain ways at different times of year. The key question is what is causing the jet stream to shift in this way? There is some research to say some parts of the natural system load the dice to influence certain states of the jet stream, but this loading may be further amplified by climate change."

There are several factors which could be 'loading the dice', including declining Arctic sea ice, solar variability, long-term ocean cycles, and other long-term cycles of natural variability. The workshop focused on the latest research looking at how these drivers can influence weather patterns and discussed how future research can be targeted to develop understanding.

For more information see our news blog:

Media coverage on 'wet summers for a decade' http://metofficenews.wordpress.com/2013/06/19/media-coverage-on-wet-summers-for-a-decade/

Guest blog: How the Atlantic may influence wet summers http://metofficenews.wordpress.com/2013/06/19/guest-blog-how-the-atlantic-may-influence-wet-summers/

Inspiring the next generation

The Met Office has a strong educational focus and lots of science to share. We offer a variety of fun and interactive opportunities and resources to encourage young people to become interested in weather and climate.

In May, we launched Rain or Shine, a new daily weather forecast for children. The daily forecasts provide children with a quick, fun and easily digestible view of the weather.

Rain or Shine is available on our Education YouTube channel and the TeacherTube website. The forecasts, prepared and presented by specially trained Met Office forecasters, provide a resource for teachers to use to plan lessons.

In June, Met Office Science, Technology, Engineering and Maths (STEM) ambassadors were at The Cheltenham Science Festival, one of the UK's leading science festivals. We offered people the chance to have a go at presenting the weather forecast as well as showcasing our work with EDF Energy to educate young people about climate science.

We also contribute to 'The Pod' – a website created by EDF where registered schools can access free teaching resources, download activities, blog and share ideas on sustainability.

Check out Rain or Shine at www.youtube.com/user/MetOfficeLearning

Find out more about The Pod at www.metoffice.gov.uk/education/collaboration/edf

Aberdeen office relocates

The Met Office in Aberdeen has moved into larger premises to deliver an extended range of operational services.

The Met Office in Aberdeen has been a fixture in the Scottish landscape for over 70 years. In that time it has developed a reputation for expertise in providing services for a range of industries including marine, renewables and offshore oil and gas – not only in Scotland but across the world.

The latest move to Lord Cullen House makes it possible to increase our forecast capability and to extend our range of services. The new Met Office forecasting centre for Aberdeen was officially opened in April by Professor Muffy Calder, Chief Scientific Adviser for Scotland. The opening was attended by members of Scottish Parliament, Members of Parliament and Professor Julia Slingo, Met Office Chief Scientist.

The Scottish Environment Protection Agency (SEPA) has a dedicated area within the Met Office. Richard Brown, Head of Hydrology for SEPA, said: "The Met Office and SEPA work closely together throughout the year to help minimise the impacts of severe weather and flooding through joint initiatives, such as the Scottish Flood Forecasting Service. This new workspace allows experts from both organisations to continue our partnership working and utilise the data from the increased forecasting capabilities within the new building."

Making the most of summer

Whatever happens with the weather, summer is for most people, a time for fun and relaxation. So, building on the success of our online winter campaign that attracted over 400,000 visitors to the web pages, we have developed a new section on our website called 'Get ready for the Great British summer'.

The collection of web pages focuses on leisure and wellbeing. They outline a diverse mix of activities to help people make the most of the summer – come rain, shine or even heatwave. It is designed in a magazine format, and presents the information as short articles, grouped under separate sections: Be active, Entertain, Relax and Explore.

While the winter version gave practical advice aimed at saving lives and protecting property during a severe winter, the summer campaign will balance the fun, entertaining side of life with practical tips for coping with more extreme temperatures or conditions. After all, Britain rarely has a summer where every day is the same. It will also directly link to the usual Met Office forecast web pages and services such as our Heat-Health Watch, UK UV forecast map and pollen alerts.

Getting together

The site is a collaborative effort between the Met Office, its partners, charities and other organisations – and therefore links to a wide range of incredibly useful information. So if, for example, we suggest trying sailing or windsurfing on a warm, windy day, there's a link to RNLI and beach safety advice – and possibly Cancer Research UK, for how to avoid sunburn and stay hydrated. For an article on the perfect woodland walk, the Forestry Commission provides the dos and don'ts of preventing a wildfire.

There will also be opportunities to feature less obvious pursuits, such as building a natural windbreak in your garden, or having a barbecue using recipes from celebrity chefs or supermarkets. And if it's raining outside, we even recommend particular books and films to enjoy while curled up on the sofa.

Social connections

The site will also be linked to the Met Office's events calendar, so people can check on the different types of sports happening around the UK, including tennis at Wimbledon. Social media, such as Facebook, will also feature – linking to articles and photos of people's summer experiences.

We're also running interactive blogs, aimed primarily at the media. These create the opportunity for the Met Office to write news and create content on all kinds of things – from records being broken in sport to 'did you know?' facts about the weather.

Looking ahead, we hope to build on the collection of online winter and summer campaigns and develop this interactive part of the Met Office site even further. As more content, news and stories fill the pages, it's easy to see how they could take on a life of their own – showing, sharing and discussing all the different things people can do – whatever the great British weather has in store.

Find out more at www.metoffice.gov.uk/get-ready-for-summer

Keeping it chilled

After the coldest spring in the UK for more than 50 years, many people were left wondering why it was so cold.

Now, in the middle of summer, it may seem like a distant memory but just a few months ago we were experiencing the fifth coldest spring in national records dating back to 1910. Throughout the cold spell, which became established through February, Met Office forecasts and warnings gave accurate and timely advice to the public, emergency services and business across the UK.

The exceptionally cold March was most noteworthy with persistent easterly winds and some significant and disruptive snowfall. With a mean temperature of only 2.2 °C (3.3 °C below the long-term average), this made it the coldest March since 1962. In fact it was the second coldest March in the UK record since 1910.

Cold weather continued through the Easter weekend and into mid-April. April's mean temperature was slightly below average, but was actually the same as 2012. Then, cooler than average weather in the second half of May helped make this spring one of the coldest in more than 50 years.

The colder than average conditions were caused by frequent easterly and northerly winds which brought cold air to the UK from polar and northern European regions.

This spring goes against recent form for the season, with eight of the past ten years being warmer than average compared to the long-term (1981-2010) average of 7.7 °C.

Overall, spring in the UK was a little drier than the long-term average with 91%. March was a dry month in the north and west while April was rather dry across much of England and Wales. May was wetter than average for the UK overall. There was snowfall in some areas during late March and early April.

Sunshine totals for the UK were very close to normal for the season with 99% of the long-term average. March was fairly dull with 81%, April was sunnier with 114%, and May was close to average with 96%. The season ended a run of six consecutive sunny springs from 2007 to 2012.

Why was it so cold?

Several potential drivers may predispose the climate system to a state which accounts for the second coldest March in the UK record since 1910. Met Office Chief Scientist, Professor Julia Slingo OBE, was interviewed by the Financial Times about the possible causes of the cold start to spring.

Read the article from the Financial Times about the causes of the cold start to spring on Barometer online: www.metoffice.gov.uk/barometer/features/2013-05/met-office-probes-britains-cold-snap

5th

coldest spring in national records dating back to 1910

2.2°C

mean temperature (3.3°C below long term average)

From field to fork

The weather is a fundamental part of gardening. Following the cold spring and exceptionally wet summer of 2012, we made a video with the team at River Cottage to see how they are affected by the weather and the seasons.

The video, 'Field to fork', is featured on the Met Office YouTube channel www.youtube.com/user/TheMetOffice

The power of climate science

Climate Service UK will help decision-makers manage opportunities and risks arising from climate variability and change both in the UK and abroad.

Throughout history, society has faced risks arising from natural variations in climate. Today, society faces additional challenges from human-induced climate change. However, we are now able to be more strategic in our response to climate-related risks and opportunities due to our expanding knowledge of climate science, ever-improving climate forecasts and growing understanding of how climate hazards impact society and the environment. The need for information and tools to help society navigate the challenges of a changing climate is real and urgent.

Every year, there is ever growing evidence of society's vulnerability to extreme weather. In 2012, for example, the UK began the year with a drought and a warm, dry first three months. This was abruptly followed by an exceptionally wet period for most of the country. 2012 eventually became the UK's second wettest year on record since 1910. There were serious consequences, especially on farming and infrastructure. There are numerous examples beyond the UK: droughts across large parts of the United States, heatwaves and wildfires in Australia, flooding in Pakistan, heatwaves in Brazil and Russia – the list is long.

Recognising that advice is needed worldwide to support decisions on managing exposure to climate variability and change, the World Meteorological Organization (WMO) and other United Nations agencies have created the Global Framework for Climate Services (Global Framework) with strong engagement from users, donors and service providers worldwide. The Global Framework will ensure climate information is used effectively in decision-making at the global, regional and national levels.

National frameworks to empower decision-makers

The Global Framework calls for countries to establish their own national frameworks with their national meteorological services as they are likely to be well positioned to undertake a central role. The national framework needs to identify and coordinate activities relating to the development and provision of climate information, products and services to meet national needs. Engagement needs to take place between the users of climate information; the organisations that maintain the official climate record, develop operational climate products and provide climate science inputs to climate services; and the organizations that provide authoritative, credible, usable and dependable science-based climate information and advice.

As WMO Secretary-General Michel Jarraud stated, "National frameworks for climate services are vital for empowering decision-makers to respond to the risks and opportunities of climate variability and change."

''This is a fantastic opportunity to deliver the value of the government's investment in climate science.''

In the UK, the Met Office is ideally placed to deliver to this remit. "We already have strong relationships in place both nationally and internationally which we can now build on to establish devoted climate services," explained Kirstine Dale, Head of Climate Programmes for Government.

Chris Hewitt, Head of Climate Service Development at the Met Office, has been working with the WMO and other key UN Agencies since 2011 as part of the core team developing the Implementation Plan for the Global Framework. He is, therefore, well qualified to ensure that the activities of the Met Office and its partners align with, and support, international activities.

Building on strengths

The UK has developed close interactions between research councils, universities, the Met Office, stakeholders and end users both at home and overseas. The UK has world-class capabilities that will allow it to take a leading role in developing and delivering climate services. The Met Office already provides services at the national scale (for the UK and for other nations) as well as regionally and globally based on strong collaborations. It will develop these further, particularly to draw on multidisciplinary expertise to support decision-makers.

The Met Office, particularly through the Met Office Hadley Centre, and other climate centres, is constantly expanding the observations and

monitoring of past and current climatic conditions, making advances in forecasting the regional climate and climatic extremes for the coming seasons, and improving the understanding of climate change.

"The power of climate science is realised through the decisions it supports," explains Kirstine. "Major developments in the underpinning scientific capability are exciting but the real power of the science in the decisions it supports."

Into the public eye

An event to showcase Climate Service UK as the Met Office's response to the Global Framework took place on 3 June at the Institute of Physics in London. Over 100 leading figures from UK government, academia and business attended the event. UK Secretary of State for the Department of Energy and Climate Change Edward Davey and WMO Deputy Secretary-General Jerry Lengoasa presented keynote speeches. The Met Office is taking a lead in showing how science can be drawn on to deliver real value both nationally and internationally. "This is a fantastic opportunity to deliver the value of the government's investment in climate science," said Kirstine Dale.

Climate Service UK creates the necessary framework for providing support and advice for managing climate-related risks and opportunities. It will draw together the necessary expertise to meet the needs of society and its decision-makers, both in the UK and overseas. By working with users to understand their vulnerability to weather and climate, it will support timely, far-sighted and well-informed decisions to address the risks and opportunities posed by a changing climate. Through Climate Service UK, the Met Office will promote sustainable growth in the face of extreme weather and climate challenges, meet international capacity-development objectives, and provide a framework for ensuring that public investment in climate science can be used to maximum effect.

Climate Service UK is the next stage in ongoing developments at the Met Office and in the UK. The Met Office Hadley Centre Climate Programme, funded by the Department for Energy and Climate Change (DECC) and the Department for Environment, Food and Rural Affairs (Defra), was launched on 20 June 2012. It has enabled the Met Office to take a leading role in delivering the national climate capability. This is the core science used to help Government to make decisions to advance the UK toward becoming more resilient to climate variability and change. Just one year on, the Climate Service UK shows how that science is being used to deliver real value.

Risk and opportunities

Secretary of State Davey is confident that Climate Service UK will make the most of world-leading climate knowledge here in the UK and further afield. "Climate Service UK builds on a foundation of world-leading science," he said, "and I'm sure will become an essential framework for advising on the risks and opportunities of a changing climate."

Those two words, "risks" and "opportunities," demonstrate how wide-ranging the service is. Climate Service UK does not just provide advice about the risks that can arise from variations in the climate, it also enables opportunities for growth and development. A growing number of countries are utilizing the expertise at the Met Office to help them understand climate variability and change and assess their risks and opportunities. Climate Service UK, along with key collaborators and partners at the national, regional and global levels, will contribute to the successful implementation of the Global Framework.

Science and technology across the board

Andy Brown and Charlie Ewen have recently been appointed to the Executive of the Met Office, as Director of Science and Chief Information Officer respectively. We asked them about the role of science and technology in the Met Office.

For Director of Science Andy Brown, a career at the Met Office was the logical conclusion after a Physics degree at Oxford. Meanwhile Chief Information Officer Charlie Ewen started his career in the RAF before working in a number of FTSE150 businesses and setting up a successful technology company.

Charlie has no doubt he is in the right place.

''If you want to be at the cutting edge of technology, there are only a handful of other brands in the UK that would enable you to work at the same scale and span of technologies that we do.''

Similarly, Andy takes great pride in the huge range of world-leading science carried out in the Met Office.

Ask either Charlie or Andy about the role of science and technology at the Met Office and they will point you towards the 'bow-tie' representation of the organisation. On the left hand side are the Met Office's scientific and technological capabilities, and on the right hand side are the services they deliver to customers.

The diagram shows that the organisation has to translate fundamental science to create relevant products and services for customers. Technology is instrumental in this. "On the left hand side you have the technology associated with an academic research association," explains Charlie, "And in the middle you have the operational infrastructure that is as resilient and robust as anything in the retail environment. On the right hand side you have all the technology to support all the very large scale web presence, including the most visited Government website in the country."

From science to service

The flow from capability to service delivery is crucial to the Met Office's ongoing success. To make sure it continues to function effectively, Charlie and Andy have been involved with a number of new initiatives.

Firstly, a series of workshops – that focused on particular customer sectors, such as utilities and insurance – have brought together staff from science and business teams to investigate how best to meet customer needs. The business teams shared insights into what customers are hoping to see in the future. Meanwhile the science teams reported on the new capabilities that have been developed over the last two years, such as the high resolution forecasting for the UK.

Collaboration like this can lead to new initiatives, and new opportunities at both ends of the bow-tie, as Andy explains:

''The crucial thing is making sure we have both the customer understanding and the science capability understanding, so they can push and pull both ways.''

The application of science

Alongside the workshops, Andy's team has also been working on a new applied science and scientific consultancy directorate, led by Doug Johnson. The Met Office focuses on delivering customer-relevant science, and to that end we are looking at how we translate science through to particular business sectors. "It's something we've always done well," says Andy, "but we want to do it better still." The team has been identifying roles within certain sectors, making sure that there are more scientists who bridge between the deeper science and its customer-focused application.

Technology shaping change

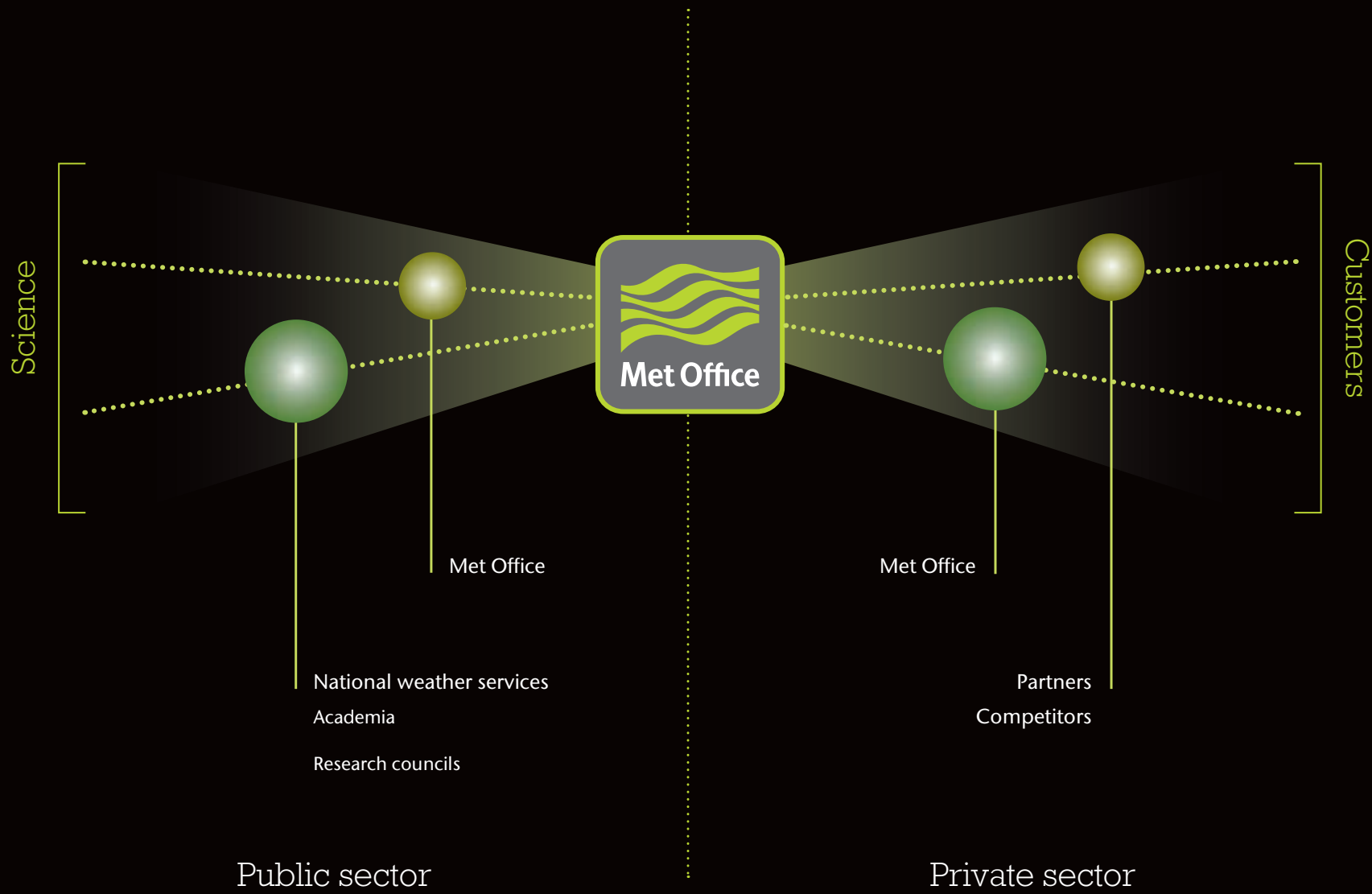
There have also been some exciting developments in Met Office technology. Information Communications Technology is an office-wide strategy to encourage everyone to engage with ICT. As Charlie says, "IT is beginning to have a role akin to science. It can deliver new capability and, in a commercial sense, new strategic advantage." The ICT strategy is encouraging everyone to see the technology used as a force for change rather than a tool for delivery.

Andy is sure that technology will continue to have implications in his field too. "Aspects of both the underpinning research and the translational science work will change because of the changes in the technology available," he explains.

Both Andy and Charlie see science and technology continuing to drive work and deliverables at the Met Office. Andy points out that science will not only be used to improve forecasting and weather, but to broaden the scope of what the Met Office can do for customers. Climate Service UK is an excellent example of this, using science to give people the best possible climate information to help them make decisions.

Communicating this to customers is vital, adds Charlie. They increasingly expect to see data-driven products that visualise weather and forecasts, so his team is working closely with the Communications team to create infographics and informatics to disseminate information. "Data-driven products on climate services are definitely coming," says Charlie.

Operationalising science and data for UK Government, public and business



Access to reliable, regular weather forecasts is considered part of everyday life for many people across the globe. But what about areas of the world with less developed infrastructure? A long-standing programme by the Met Office, working in partnership with national weather services in developing countries and others such as the World Meteorological Organization (WMO), has helped deliver weather forecasts via television to over 40 developing countries. And one such country recently became the first to enjoy a digital upgrade.

Forecasting for African skies

Ethiopia was the first country to benefit from a media studio, implemented through the Met Office's contribution to the Voluntary Cooperation Programme (VCP) when, 20 years ago, technicians installed a custom made mini studio at the National Met Agency (NMA) in the capital. Then, at the end of 2012, another first: Ethiopia's NMA was given a digital upgrade for their media studio. Met Office Media Consultant Dave Robinson and Studio Manager Steve Fallon were there, on-site in Addis Ababa, to implement the improvements.

"We were there for 10 days and began by stripping out the old studio equipment to replace it with newer equipment," says Steve. "We then moved onto replacing the analogue tape system with a digital recording system that provides high quality recordings with a streamlined production process and reduced running costs."

The upgrade enables the Ethiopian National Met Agency to broadcast weather reports far closer to the time they are recorded, using the free internet delivery service, DropBox. This is a huge improvement to the service as previously, broadcasting the weather involved transporting videotaped forecasts across the city's congested roads to the national TV station – a process that would routinely mean a one hour round trip. And that was just the beginning because getting forecasts out to regional stations could mean journeys of 100 km or more, along roads of varying condition. This made it impossible to guarantee daily forecasts, despite rural communities often being the most at risk from extreme weather events.

When time is of the essence

Using DropBox as a delivery tool makes it possible to give the people of Ethiopia more frequent forecasts much more reliably, which is a huge help for their day-to-day life. But the speed of delivery has further advantages including alerting the public to severe weather conditions in good time and even cost savings for the NMA through reduced use of fuel.

TV broadcasts are complemented by radio versions, which also benefited from the upgrade. Not only can the files be emailed, but also a high-quality studio microphone ensures a clearer, more professional end result. Of course, providing a great service is about more than equipment.

"We provided training on how to use the new technology and how to make the most of our weather graphics system, WeatherEye," says Steve.

WeatherEye makes forecasts more accessible via slick animated sequences and graphics that include weather symbols, 3D maps and wind speeds. It is the preferred system for

many TV broadcasters in the UK and is used on the ITV News and Daybreak. Its simple, interactive system proved popular in Ethiopia too:

"We had the opportunity to meet with the directors – the key decision makers," explains Steve. "Once they saw what we could do with our graphic software, they were blown away."

Ethiopia won't be the sole country to benefit from this kind of upgrade. Dave is running a media workshop in Kenya this June and visiting Dominica later this year. What's more, national weather services across Africa will converge on Nairobi for training on WeatherEye, digital production workflow and, very importantly, branding. Having greater brand awareness is vital for national weather services in different countries to attain greater self-sufficiency. Being able to brand their service specifically for their audience – encompassing all the cultural nuances of the region – opens up greater commercial opportunities.

Back at base camp

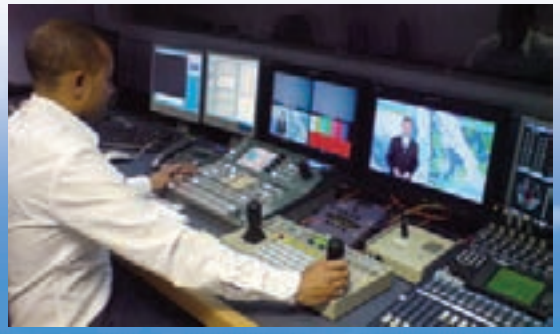
Support continues back at the Met Office headquarters in Exeter too, via the website www.met-elearning.org/moodle, which Steve describes as "an online reference for technical help and assistance, complete with forums." It's also a resource to help developing countries communicate with each other.

The VCP in detail

The Voluntary Cooperation Programme (VCP) is run by the World Meteorological Organization (WMO), a specialised agency of the United Nations made up of 191 members.

Its aim is to enhance weather and climate services worldwide and, ultimately, aid sustainable development. This ranges from supporting the collection of weather and climate observations to university fellowships and the effective dissemination of weather forecasts and warnings to the public. The Met Office's and UK contribution to the VCP comes from the government-funded UK public weather service (PWS).

While further developments will rely, in part, on the infrastructure of Ethiopia and improving the speeds and dependability of the internet, the upgrade to the system has instantly improved the quality and professionalism of broadcasts. Thanks to their work through the VCP, the Met Office will continue to roll out its programme of weather media upgrades to the countries that need it most.



"We provided training on how to use the new technology and how to make the most of our weather graphics system, WeatherEye."

After last year's wet summer and some recent challenging winters, few of us need reminding that the only certainty about Britain's weather is how changeable it is. In extreme weather, transport is often affected. That's why the close ties between the Department for Transport (DfT) and Met Office are so important, as Lucy Chadwick, Director General of International, Strategy and Environment Group for DfT, explains.

Important transport links

Whatever the time of year, it's never too early to think about what's round the next seasonal corner and get ready for whatever the weather throws at us. In times of severe weather, floods and other natural hazards such as volcanic ash, DfT and our executive agencies, the Marine and Coastguard Agency and Highways Agency, work closely with the Met Office to protect lives and minimise disruption on land, at sea and in the air.

Snow, biting winds and plummeting temperatures take their toll on our transport networks. So, it is in winter especially that the DfT and Met Office engage. In recent years, the UK has experienced extreme winters. Even during milder winters, there can be severe ice and snow. We are also well aware that regional contrasts and daily differences can be significant – as well as the possibility of severe conditions outside of the core winter months of December, January and February – hence the importance of our close working relationship with the Met Office.

Contingency planning

Flooding has the potential to cause huge problems to the transport network, both during winter and summer, so we routinely use Met Office advice for risk assessment and contingency planning, as well as daily operations. In extreme weather situations DfT has access to further forecaster support. Regular operational forecasts enable my department, and the transport sector more widely, to flex resources to meet the variability for contingency planning and resilience.

Met Office Advisors provide expert guidance to civil contingency planners and emergency responders, both in pre-winter planning and operationally whenever severe weather occurs. The accuracy of Met Office short-range forecasts is very high and the Met Office 1-5 day forecast and severe weather warnings help Government, local councils, train, airport and road operators, to minimise the impact of severe weather.

DfT now has a high-level understanding with the Met Office which sets out basic working principles. If severe weather is expected, the arrangement can speed up facilitation of a dedicated forecaster. DfT and Met Office communications teams also work closely to ensure messages are accurate and aligned across government.

Close working relationship

To help keep roads open we work closely with local authorities. Through the Highways Agency we've introduced a new Weather Information Service so everyone involved in gritting and snow-clearing has accurate, up-to-date forecasts. To let motorists know how their journeys could be affected by severe weather, there's even a Met Office forecaster in the Highways Agency's National Traffic Operations Centre.

On our railways, we've invested to help train operators keep tracks clear from snow and flood water. We haven't forgotten the impact that extreme weather can have on airports and lessons have been learned. Heathrow has a £50 million resilience investment plan and aware of the benefits an embedded Met Office forecaster has brought to the Highways Agency, Heathrow has now followed suit.

In extreme conditions, how, when and where we travel will always be affected to some degree. It's unavoidable, even in countries that regularly experience harsh winters. What really matters is taking the time to prepare. After that, what matters is the speed of response, the effectiveness of mitigation measures and the time it takes for transport networks to recover. These are key components of effective resilience and they're at the heart of this Government's efforts to keep the country moving. So, while the Great British weather will do what it does, through our important links with the Met Office, we are better prepared to deal with the challenges nature throws at us.

What has looking into the meaning of a single word got to do with analysing the impact of natural hazards like droughts, thunderstorms and landslides? A closer look at the achievements and aspirations of the Natural Hazards Partnership reveals all...

A defining partnership

Set up in 2011, the Natural Hazards Partnership is a collaboration of more than 15 research centres and agencies that share a vision to provide research, analysis and operational advice on potentially dangerous natural events. Their audience is made up of governments and emergency responders – and their work helps these organisations create more effective policies, communications and services.

In practice, this involves bringing together scientists from a range of backgrounds to share information and knowledge, and then communicating it with the right people. From the start, the Met Office has played a significant role in making that a reality, getting involved in projects that range from developing new technology that helps quantify the impact of natural hazards to producing factsheets for easy reference. We have even looked closely at the language used by scientists – going right down to the level of individual words – to make sure everyone's clear on all terms and definitions being used (see box for more info about the main projects).

The Met Office's Paul Davies has led the development of the Natural Hazard Partnership from the beginning. In the aftermath of the severe floods of summer 2007 – and in response to the subsequent Pitt Review – Paul was Chief Hydrometeorologist at the Flood Forecasting Centre, a successful joint initiative between the Met Office and the Environment Agency. In this role he worked closely with the natural hazards team in the Civil Contingencies Secretariat within the Cabinet Office.

At the time, Paul was forging links with a range of specialist agencies and spotted an opportunity to make the most of the combined talent and knowledge. With the support of the Cabinet Office, Paul set the wheels in motion and quickly received very encouraging results. "There are too many people to acknowledge individually in this short article, but it was immediately apparent how much everybody believed in the idea," says Paul.

But it was important for Paul and others involved that the results they achieved spoke for themselves. "We agreed very early on that we wanted to be judged on what we do, not just what we say."

Within a month, the partners had agreed what projects they would work on. And from that day onwards, the ethos of sharing, innovation and getting things done has been key to the development of the Partnership. It has English, Welsh and Scottish government representatives plus the potential for Northern Ireland to join soon.

The partnership's projects aim to make a genuine difference to its key audience – so to help ensure standards, it operates under the watchful eye of a representative advisory group.

"They challenge us and steer us," says Paul. "They test our products for usefulness and relevance and help us plan how to roll out services."

The advisory group adds real value to the partnership's projects, helping to avoid duplication or confusing work that is already being done. "The NHP is about complementing existing services, not developing a separate operation", says Paul. "We're there to support the work of each of the partners."

The value of the partnership and its work is attracting widespread recognition. After a recent international conference, 'Building resilience to natural hazards,' it was commended in a report from the European Commission as a successful example of how science can be connected to operations and policy makers. Member states are now looking into how a similar partnership might work Europe-wide.

With such high praise – and with a developing business case that may attract additional funding – the future looks full of opportunity for the NHP. "We're exploring possibilities of cementing and enhancing the work that's already happening," says Paul, "but we won't lose sight of the spirit of the partnership. The key thing is that we're all in it together – everyone shares and everyone benefits. And we'll just keep building from there."

"We're there to support the work of each of the partners."

The aim of the Natural Hazards Partnership is to be a one-stop-shop that provides early warning of extreme weather events and natural hazards.

Key projects by the Natural Hazard Partnership

- **National Risk Assessment (NRA)**
  Providing scientific input to the NRA, the government method of monitoring the most significant emergencies that the UK and its citizens could face over the next 5 years.

The following projects are currently being developed by the partners for future delivery to the emergency response community:

- **Daily Hazard Assessment**
  At-a-glance, five-day outlook for natural hazards, which might affect the UK. Includes links to partners for more detailed information.
- **Hazard Impact Model**
  Ongoing development of new technology based on information gathered from a variety of partners, to quantify the impact of certain hazard scenarios.
- **Factsheets**
  Easy-reference info about a range of hazards and the science behind them specifically targeted at responders. Currently this covers drought, wind, landslides, space weather, inland flooding, wildfires and snow and ice.
- **Communications**
  Close analysis of the language used to communicate the science. Establishing clarity across the partnership around crucial terminology e.g. 'predict', 'forecast,' as well as hazard-specific language.

The Met Office has been refining and improving the accuracy of its forecasts for decades. However, assessing the level of accuracy isn't straightforward so we employ a complex system called 'verification' that compares our predictions with 'the truth' that actually occurs.

The value of verification

There's a debate in the scientific community as to what actually constitutes 'truth' in forecasting, but taking any uncertainties into account, the Met Office uses a wide range of observations to get the most accurate picture possible. These include data from synoptic reporting stations (SYNOPS) and airports (known as METARS) on land, weather buoys on the ocean, weather balloons and aircraft. Radar data has been used for some time to verify rainfall forecasts and satellite data are also becoming increasingly important – and there are many other sources besides.

Verification systems assimilate these observations and compare them with our forecasts, producing a range of verification scores that can be applied over areas or multiple sites and over defined time periods.

Monitoring and refining this process are two teams of scientists and scientific software engineers with a shared expertise that covers meteorology, data analysis, scientific programming and database skills. And as Philip Gill, Operational Verification Team Manager points out, "Communication skills are also really important – so we can clearly impart results to our customers, our scientists, and the wider scientific community."

Why verify?

Verification is invaluable. From a scientific perspective, it's an objective way to monitor the performance of forecasting models – and to test whether any changes made to those models actually lead to an overall improvement. It also enables us to assess our corporate performance through the Forecast Accuracy Business Performance Measures, as well as the Key Performance Indicators agreed with customers.

We also participate in the World Meteorological Organization's Commission for Basic Systems (WMO-CBS), which offers a standard protocol for exchanging verification data with other meteorological services around the world. And of course, verification allows the Met Office to demonstrate the accuracy of its forecasting products to customers in an objective way. Many of these products are routinely verified, so customers can see how well they are performing on an ongoing basis.

So how accurate are the Met Office's forecasts? As Philip Gill explains, "It depends on the parameter, location and time period you're looking at, but in general, we're always improving." At the moment for example, our day ahead forecast for maximum temperature for the UK is accurate within two degrees over 90% of the time, while our day ahead wind speed forecast is accurate within five knots over 90% of the time.

But perhaps the clearest indicator is the Met Office Core Capability Component which measures the accuracy of the mean sea level pressure forecast. This may sound less familiar, but it's actually one of the fundamental parameters used in weather forecasting. "Looking at this particular measure," says Gill, "our four-day forecast today is as accurate as our one-day forecasts were in 1980."

Over 90%

of our next day maximum temperature forecasts are accurate within 2 °C

Over 80%

of our next day minimum temperature forecasts are accurate within 2 °C

94%

of our 3-hourly temperature forecasts are accurate within 2 °C

Over 90%

of our next day wind speeds forecasts are accurate within 5 knots

Our four day forecasts today are as accurate as our one-day forecasts in 1980.

This overall trend towards ever-greater accuracy is down to ongoing development of the Met Office's models, the ability to assimilate more new observations, and also improvements in the Met Office's supercomputer technology.

Meeting perception with reality

It's all very well having objective data about forecast accuracy – but what is the customers' view? Here's where the Met Office Customer Attitude Survey is so important. In the survey, customers can express what they perceive the accuracy to be – and this feedback is taken very seriously. "A lot of the comments we get back are very positive," says Gill, "but if a customer's perception doesn't match up with our verification statistics, we're able to go back to them and address any concerns." As such, verification is a vital tool to support and really strengthen the relationships the Met Office has with its customers.

For more on the Met Office's forecast accuracy, visit www.metoffice.gov.uk/about-us/who/accuracy/forecasts

Making it matter

It's not enough to simply generate verification data – it has to be relevant as well. That's why the Met Office verification teams work on breaking down statistics in ways that are most useful to each of our customers.

For example, say a customer needs to know when the temperature will drop below freezing, so they know when to grit the roads. We can generate a simple report with four possible outcomes: a hit is when the temperature is forecast to go below freezing, and it does; a miss is where it is forecast not to drop below freezing and it does; a false alarm is where it is forecast to go below freezing and it doesn't; and a correct rejection is where it is forecast not to drop below freezing and it doesn't. From counting numbers of each of these outcomes, we can provide summary figures such as percent correct and false alarm rate.

We are also able to express verification in economic terms as a Relative Economic Value score. If a customer knows what their relative costs and losses are when they make decisions based on forecasts, this score could enable them to calculate the possible cost saving a particular product could give them.

Drought, floods, rising sea levels, more intense tropical cyclones. Our changing climate has a direct – and indirect – impact on the availability of food and people's access to it. Food security, as it's known, is an incredibly complex issue – but one that many organisations including the Met Office are tackling head on.

Hunger in a changing climate

At present, close to one billion people suffer from hunger – and studies suggest that the impact of climate change could increase this figure by between 100 to 200 million people by 2050. But as Kirsty Lewis, Principal Climate Change Consultant and Food Security Team Leader explains, this is just one part of a very complex picture: "We need to look at the contribution of climate change to food security overall."

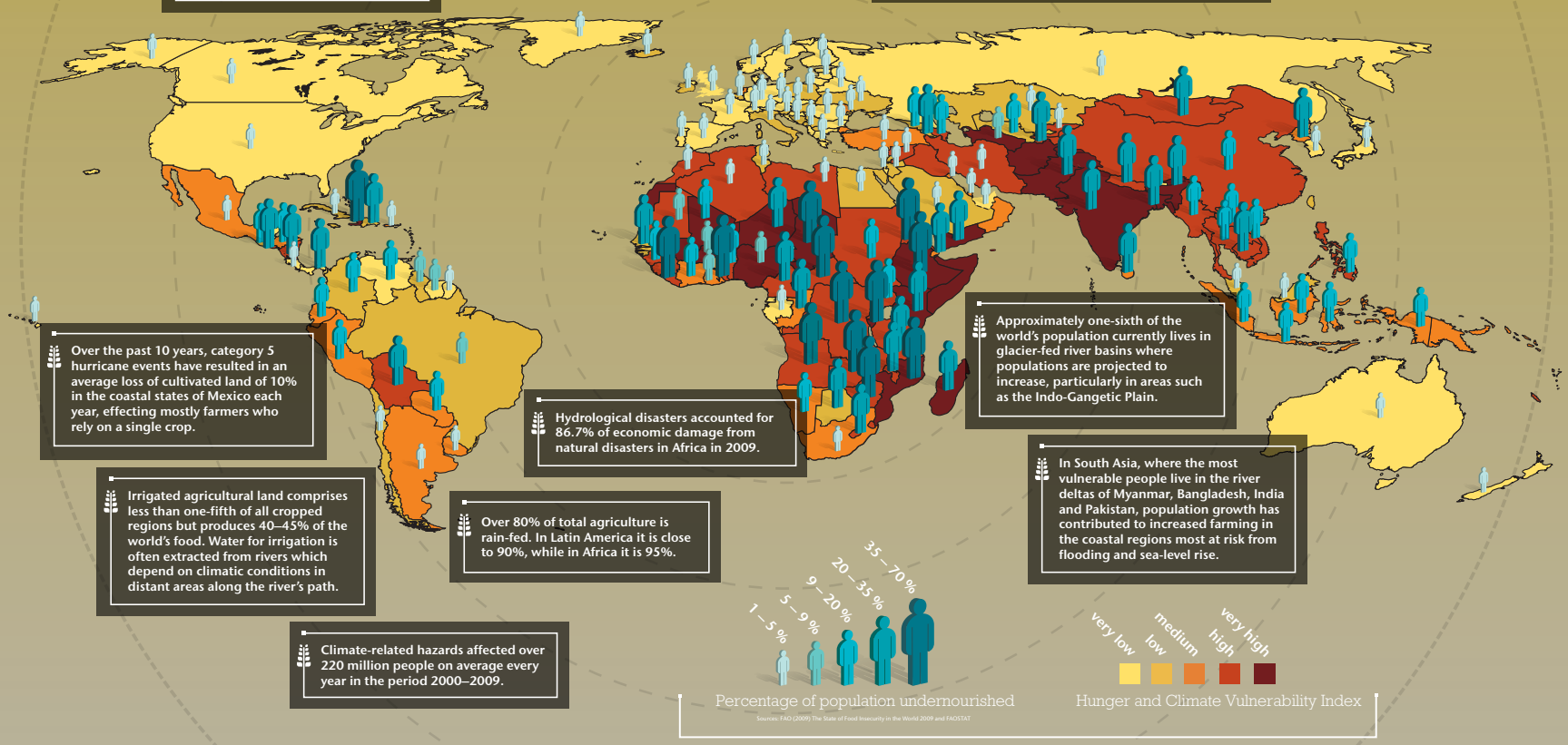
While there is uncertainty about the impact of climate change on a local scale, climate scientists agree that the global average temperature is rising. In some areas this could increase the length of growing seasons and reduce loss of yields due to frost. But on the other hand, such changes in climate could also bring more extreme weather events such as flooding or drought, damaging crops in the process. ➔

Food insecurity and climate change

It is estimated that, on average, for every United States dollar invested in risk reduction, US$2–4 are returned in terms of avoided or reduced disaster impacts.

Heatwaves became more frequent over the 20th century. In the summer of 2003, Europe experienced a particularly extreme heat event. A record loss of 36% crop yield for corn occurred in Italy.

In 2010, the Russian drought resulted in wheat yield reductions of 40% in key production areas, and the Pakistan floods resulted in losses of half a million tonnes of wheat. Together with market speculations, these events led to price increases.



Over the past 10 years, category 5 hurricane events have resulted in an average loss of cultivated land of 10% in the coastal states of Mexico each year, effecting mostly farmers who rely on a single crop.

Approximately one-sixth of the world's population currently lives in glacier-fed river basins where populations are projected to increase, particularly in areas such as the Indo-Gangetic Plain.

Hydrological disasters accounted for 86.7% of economic damage from natural disasters in Africa in 2009.

In South Asia, where the most vulnerable people live in the river deltas of Myanmar, Bangladesh, India and Pakistan, population growth has contributed to increased farming in the coastal regions most at risk from flooding and sea-level rise.

Irrigated agricultural land comprises less than one-fifth of all cropped regions but produces 40–45% of the world's food. Water for irrigation is often extracted from rivers which depend on climatic conditions in distant areas along the river's path.

Over 80% of total agriculture is rain-fed. In Latin America it is close to 90%, while in Africa it is 95%.

Climate-related hazards affected over 220 million people on average every year in the period 2000–2009.

Sources: FAO (2009) The State of Food Insecurity in the World 2009 and FAOSTAT

MEAN TEMPERATURE
Average temperatures are expected to increase across the globe in the coming decades. In mid to high latitudes, increasing average temperatures can have a positive impact on crop production, but in seasonally arid and tropical regions the impact is likely to be detrimental.

MEAN PRECIPITATION
On average, an increase in global precipitation is expected, but the regional patterns of rainfall will vary: some areas will have more rainfall, while others will have less. There are high levels of uncertainty about how the pattern of precipitation will change, with little confidence in model projections on a regional scale. Areas that are dependent on seasonal rainfall, and those that are highly dependent on rain-fed agriculture for food security, are particularly vulnerable.

EXTREME EVENTS
Recurrent extreme weather events such as droughts, floods and tropical cyclones worsen livelihoods and undermine the capacity of communities to adapt to even moderate shocks. This results in a vicious circle that generates greater poverty and hunger. The impacts on food production of extreme events, such as drought, may cancel out the benefits of the increased temperature and growing season observed in mid to high latitudes.

CO_2 FERTILISATION
Carbon dioxide (CO_2) concentrations are known to be increasing. However, the effect of CO_2 fertilisation on crop growth is highly uncertain. In particular, there is a severe lack of experimental work in the Tropics exploring this issue. There is some evidence that although CO_2 fertilisation has a positive effect on the yield of certain crops, there may also be a detrimental impact on yield quality.

DROUGHT
Meteorological drought (the result of a period of low rainfall) is projected to increase in intensity, frequency and duration. Drought results in agricultural losses, reductions in water quality and availability, and is a major driver of global food insecurity. Droughts are especially devastating in arid and semi-arid areas, reducing the quantity and productivity of crop yields and livestock. Seven hundred million people suffering from hunger already live in semi-arid and arid zones.

HEATWAVES
In all cases and in all regions, one in 20-year extreme temperature events are projected to be hotter. Events that are considered extreme today will be more common in the future. Changes in temperature extremes even for short periods can be critical, especially if they coincide with key stages of crop development.

HEAVY RAINFALL AND FLOODING
While uncertain, it appears that there will be more heavy rainfall events as the climate warms. Heavy rainfall leading to flooding can destroy entire crops over wide areas, as well as devastating food stores, assets (such as farming equipment) and agricultural land (due to sedimentation).

MELTING GLACIERS
Melting glaciers initially increase the amount of water flowing in river systems and enhance the seasonal pattern of flow. Ultimately, however loss of glaciers would cause water availability to become more variable from year to year as it will depend on seasonal snow and rainfall, instead of the steady release of stored water from the glacier irrespective of that year's precipitation.

TROPICAL STORMS
For many arid regions in the Tropics, a large portion of the annual rain comes from tropical cyclones. However, tropical cyclones also have the potential to devastate a region, causing loss of life and widespread destruction to agricultural crops and lands, infrastructure, and livelihoods. Some studies suggest tropical cyclones may become more intense in the future with stronger winds and heavier precipitation. However, there is a limited consensus among climate models on the regional variation in tropical cyclone frequency.

SEA-LEVEL RISE
Increases in mean sea-level threaten to inundate agricultural lands and salinise groundwater in the coming decades and centuries. Sea-level rise will also increase the impact of storm surges which can cause great devastation.

CHANGES IN HEALTH AND NUTRITION
Climate change has the potential to affect different diseases, including respiratory illness and diarrhoea. Disease results in a reduced ability to absorb nutrients from food and increases the nutritional requirements of sick people. Poor health in a community also leads to a loss of labour productivity.

The production of this graphic was partly funded by the Government of Luxembourg.

For more information on food security and climate change and for references for the graphic, please visit: www.metoffice.gov.uk/climate-change/guide/impacts/food
or www.wfp.org/climate-change

A temperature rise could also affect globally traded food, and hit commodity prices. It may affect people's health which, in turn, affects their ability to absorb nutrients from food. It may also affect the way that food markets operate. And beyond climate, considerations include the impact of demographics, trade markets, economic growth and so on.

As Kirsty explains, "This is why it's so important that the Met Office works with other organisations. The question that policymakers are asking isn't whether crop yields go up or down; it's whether people will be able to afford food and access it securely. They want to know about the bigger picture."

Working in partnership

Over the past two years the Met Office has been working closely with the United Nations World Food Programme (WFP) – the world's largest humanitarian agency fighting hunger worldwide and responding to food insecurity within developing countries. It is a relationship that allows each organisation to work across their respective disciplines, share expertise and deliver knowledge that could help policy makers address the complex issue of food security more effectively.

One of the first joint projects has been the development of a Hunger and Climate Vulnerability Index. This simple diagnostic tool reveals the relationship between climate and food security – identifying those countries most vulnerable. The current index looks at present-day vulnerability by country – but this is just the beginning. Because it's scalable, it can be re-run on a sub-national level, and use future climate projections. It will then be possible to explore how changing one component – such as percentage of grain-fed agriculture, for example – could impact on vulnerability.

''This is why it's so important that the Met Office works with other organisations. The question that policymakers are asking isn't whether crop yields go up or down; it's whether people will be able to afford food and access it securely. They want to know about the bigger picture.''

Looking ahead, it could prove an invaluable tool for policy and decision makers to design adaptation strategies, build resilience and lower the risk of hunger.

Food security in the UK

The issue of food security is not purely a developing world concern. Closer to home, we have also been working with government bodies and companies, examining the impact of climate change on the price of commodities imported to the UK, such as rice, wheat, barley and other foods. "In the UK it's about standard of living: what proportion of your income goes on food and whether you can afford luxuries like coffee and chocolate," says Kirsty.

To really get to grips with the issues, building long-term relationships and developing a shared language is essential. The challenge is a rewarding one. As Kirsty says, "here's where you get to tackle some real-world problems." And hopefully overcome them, too.

Find out more about how the World Food Programme is responding to the challenge at www.wfp.org/content/climate-change-and-hunger-responding-challenge

How might climate change affect food security?

According to the World Food Summit of 1996, "Food security exists when all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life." Here are just a few ways climate change could have an impact:

The global average temperature is expected to increase, affecting crop production.

Although average global rainfall is expected to increase, regional patterns of rainfall will also change, leaving areas dependent on seasonal rainfall, or on rain-fed agriculture particularly vulnerable.

Recurrent extreme weather events such as droughts, floods and tropical cyclones worsen livelihoods and undermine the capacity of communities to adapt to even moderate shock.

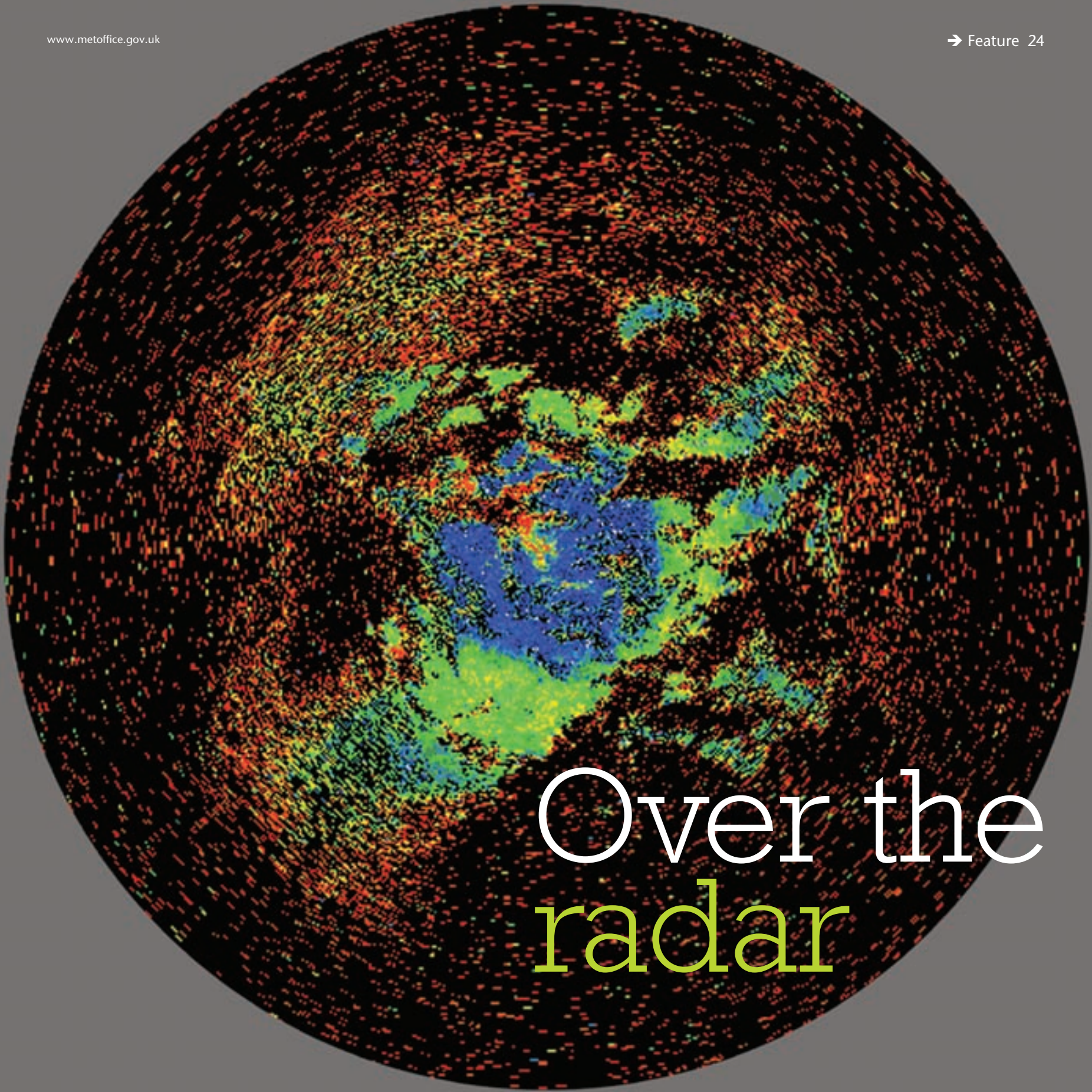
Carbon dioxide (CO_2) concentrations are increasing. While the effect of CO_2 fertilisation on crop growth is highly uncertain, some evidence suggests that while it could increase crop yields, yield quality may be adversely affected.

Heatwaves – one in 20-year extreme temperature events – are projected to be hotter. Even short heatwaves can be critical, especially if they coincide with key stages of crop development.

Melting glaciers ultimately cause water availability to become more variable as it increases dependency on seasonal snow and rainfall.

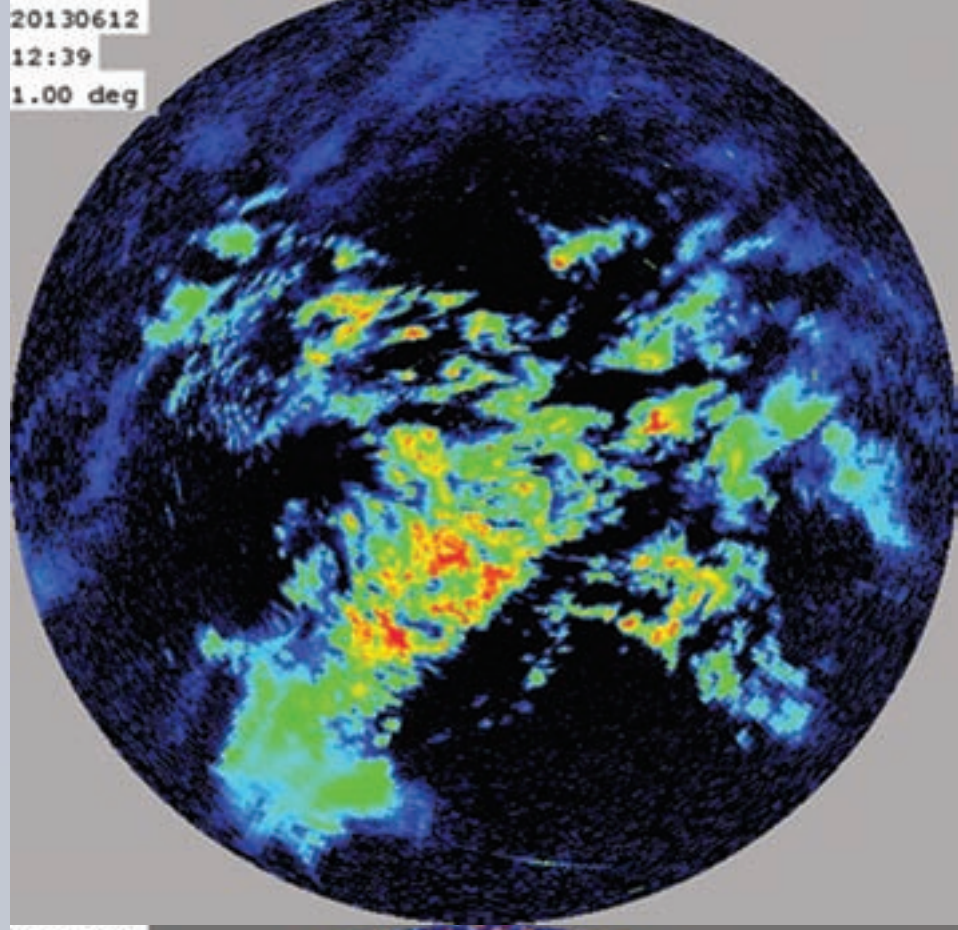
Sea-level rise threatens to engulf agricultural lands and salinise groundwater in the coming decades and centuries. It will also increase the impact of storm surges which can cause great devastation.

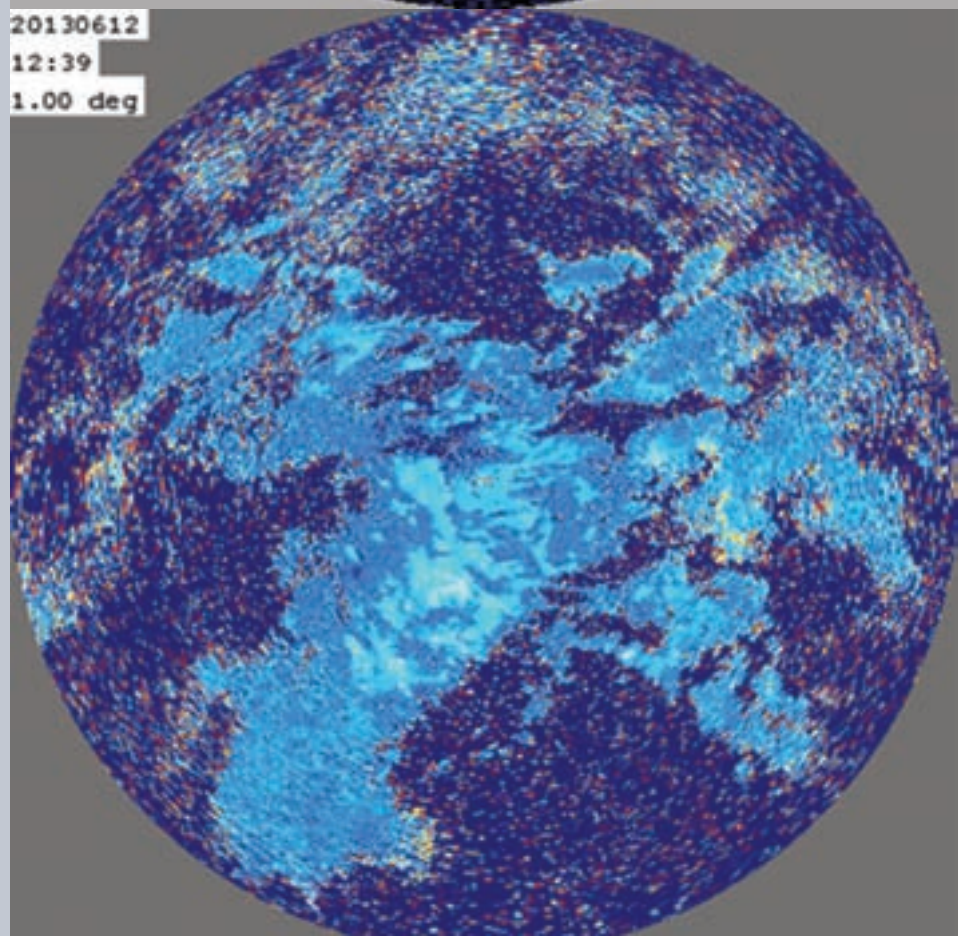
To find out more, visit www.metoffice.gov.uk/climate-change/guide/impacts/food



Over the radar

An ambitious in-house engineering project is set to transform the Met Office's radar capabilities.





The Met Office weather radar network is one of the world's longest established networks of its kind, and plays a vital part in providing our customers with timely weather information. However, some of the equipment is nearly 30 years old, and is approaching the end of its working life, limiting our ability to provide new and improved radar products.

Five years ago, the Met Office radar systems team started looking at our options to replace the network. The team soon realised that the best way forward would be to develop systems in-house. Having maintained and upgraded the radars for many years, our engineers had built up an unparalleled level of expertise in radar technology.

Flexible and cost-effective

Our engineers developed and built a receiver, a radar signal processor, and a radar control system, and sourced hardware from a range of manufacturers. The solution is based on Open System Architecture, making it much more flexible than the existing network. As technology advances in the future, the radar system will be flexible enough to adapt and upgrade. The solution also brings excellent cost-savings, as it has proved much more cost-effective to develop technology in house rather than source everything from suppliers.

"This is one of the most ambitious engineering projects we have ever undertaken," explains Jacqueline Sugier, the Radar Signal Processing R&D Team Leader. "We're not just upgrading the hardware, but the whole capability too." Whereas the old radar network used single polarisation, the new components use dual polarisation. This means the new radar will be polarised both horizontally and vertically, providing much more information on the shape of the target. We can now capture the size and shape of raindrops as well as their composition, for instance ascertaining whether they are water, ice or snow – which will lead to improvement to the accuracy of our rainfall measurements particularly during high impact weather events. The readings are also used to measure wind speed, as any changes in the frequency of the radar signal is indicative of the wind velocity blowing through the rain – in much the same way that the radar signal from a speed camera can indicate the velocity of a speeding car.

A safer working environment

In partnership with the Environment Agency, the new state-of-the-art equipment will be installed at 16 sites across the country, most of which should be fully operational by 2016. While the hardware is being installed we are also taking the opportunity to upgrade the overall structures at the radar stations. Each site has a tower of anything from 10m to 20m in height, with vertical ladders attached. During deployment we are replacing the vertical ladders with safer means of access, making it easier for engineers to access the radar equipment. Once the towers and access have been updated, it then takes around three weeks to install the system, with another three months for evaluating performance. Every new radar will be left in quarantine while readings are evaluated at our headquarters in Exeter before we make information available to customers.

Customers will benefit from more reliability straight away. "The new system is much less prone to failure than the old one," Jacqueline explains. Our scientists, in partnership with our academic partners, are now developing new algorithms to optimise the information and forecasting that the new system will provide. "We're very pleased with the quality of these new radars and the incremental benefits will start to be rolled out this year," says Jacqueline.

Not just hot air

The Met Office is currently working with the University of Reading to develop an innovative forecasting technique first proposed in Canada in the 1990s. Radar pulses travel more slowly through moist air, which means we can use the data provided by the new system to detect humidity. Consequently we will be able to identify not just when storms are happening, but when they are likely to appear.

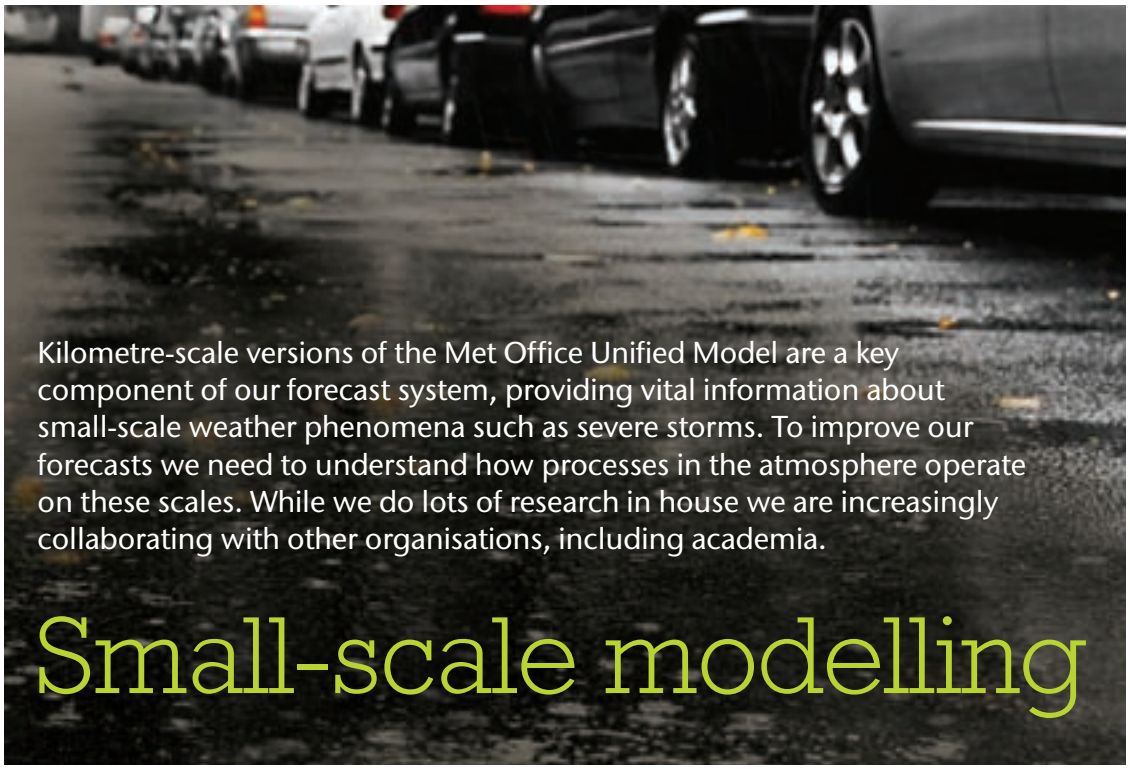
This is an exciting development that will be beneficial to professional users as well as the general public, and stems from the fact that we have created our own radar solution. "We have complete control of the signals from the raw data right through to the products," explains Jacqueline, "So we can use it to push further the boundaries of research and ultimately improve the quality of our forecasts."

"This is one of the most ambitious engineering projects we have ever undertaken. We're not just upgrading the hardware, but the whole capability too."

We are already harnessing our knowledge to offer consultancy. For instance, we recently acted as a consultant for the Caribbean Met Office, helping them to specify, select and install five radar systems in the Caribbean. We have also very recently worked closely with the authorities of Sao Tome and Principe – an island off the west coast of Africa – to assess the feasibility of installing a radar system on the island to detect and track tropical storms before they hit their fishing fleets.

The project is an exciting development for the Met Office, furthering our capabilities and delivering a more cost-effective and safer way of working. It has also been an excellent example of best practice at the Met Office. As Jacqueline says, "There is a range of skills needed across the radar team, and the team has been bouncing ideas off one another to develop this innovative solution."

To find out more, visit www.metoffice.gov.uk/climate-change/guide/impacts/food



Kilometre-scale versions of the Met Office Unified Model are a key component of our forecast system, providing vital information about small-scale weather phenomena such as severe storms. To improve our forecasts we need to understand how processes in the atmosphere operate on these scales. While we do lots of research in house we are increasingly collaborating with other organisations, including academia.

Small-scale modelling

The development of convective storms can depend very much on small scale variations in the atmosphere. These variations in winds, temperature and humidity can be placed into two categories – those linked to the surface topography, such as hills and coastlines, and those originating from larger scale structures in the atmosphere, such as fronts. Forecast accuracy can depend on the way we represent small-scale processes like convection, and turbulence in the model.

Representation of these small scale features in our forecasting model is improved if the resolution is increased by having more detailed surface data and a higher resolution representation of the atmosphere itself. To understand and improve representation of these small scale features, we are working to improve key parts of the model, in particular describing processes in the boundary layer of the Earth's atmosphere, turbulence and cloud microphysics.

This involves rerunning the model at different resolutions to replicate and examine how the model forecasts weather events of particular interest. This helps to get a detailed understanding the model's behaviour and performance alongside a more statistical view of many similar events. In addition, there is an increasing use of an ensemble forecast approach – running the model many times with slightly different starting points or formulations – to gain insight into the physical mechanisms, the nature of the predictability of local weather and how to present kilometre-scale model output probabilistically.

We are also interested in improving model representation of other weather elements such as wind and fog. Future work will investigate the benefits of very high-resolution grids of around 100 m, forecasting for urban areas and coupling high-resolution atmospheric models with ocean, wave and hydrology models which may affect the representation of important feedbacks in the combined system.

The MetOffice@Reading works closely with colleagues in academia particularly with one of our academic partners, the Department of Meteorology at the University of Reading, as well as with colleagues in Exeter. The Meteorology Department at the University of Reading has a reputation for outstanding research and has a long history of collaborating with the Met Office. We have been involved in several field projects with Reading and other universities for example CSIP (the Convective Storms Initiation Project – looking at convective storms) and are currently involved with several projects including DIAMET (DIAbatic influences on Mesoscale structures in ExTratropical storms – looking at raining weather systems), Advanced Climate Technology Urban Atmospheric Laboratory (ACTUAL – urban meteorology), the Convective Precipitation Experiment (COPE – based in South West England looking at the lifecycle of convective clouds) and the Dynamical and Microphysical Evolution of Convective Storms (DYMECS – a statistical look at the structures of showers.)

As part of DYMECS, the University of Reading radar group is looking at the properties of convective storms using the Chilbolton research radar. The Met Office benefits from access to data from the radar along with its interpretation by several world leading experts in radar meteorology. In turn, university scientists benefit from access to the Met Office Unified Model and the expertise in its use and interpretation within the MetOffice@Reading group. This aids them in the meteorological interpretation of their results and enables their work to have a more immediate impact on improving weather forecasts.

Work on convective-scale modelling within the Mesoscale Modelling group at Reading goes hand in hand with the Advanced Nowcasting Research group at Reading which is involved in high-resolution data assimilation and using novel observations. Last year, the group delivered the Nowcasting Demonstration Project to produce short-range forecasts every hour on a 1.5km grid covering much of England and Wales. This used advanced 4D-Var data assimilation to get the best possible start to each forecast. Its capabilities were showcased for the London 2012 Olympic Games and it proved to be very successful.

To find out more, visit www.metoffice.gov.uk/climate-change/guide/impacts/food

Science profile

Nigel Roberts

Expert Scientist, Convective-scale Modelling and Predictability

The Met Office employs professionals and experts who are constantly expanding the boundaries of weather and climate prediction. Here we meet one of them...

Research into high-resolution models has made it increasingly possible to accurately predict extreme rainfall, storms and other events that cause flash floods. Nigel Roberts and his colleagues are at the vanguard of this fast-developing area.

Nigel works in the Mesoscale Modelling Group at the MetOffice@Reading, based at the University of Reading. Met Office staff have been at the university for over twenty years and are actively involved with several collaborative projects, including work undertaken by academic staff and PhD students. It's a long-standing relationship that's mutually beneficial: "The Met Office benefits from access to specialised data and its interpretation along with the insights of world-leading scientists. The university benefits from access to our Unified Model and our own world-leading scientific expertise," explains Nigel.

Looking at Nigel's work over recent years offers an insight into how our high resolution models – and our forecast accuracy – have evolved.

Aiming high

Between 2001 and 2008, Nigel led the Modelling Extreme Rainfall Events and the Storm Scale Modelling Project – both partly funded by the Environment Agency and the Department for Environment, Food and Rural Affairs (Defra). These sought to establish whether a 1-km configuration of the Met Office's Unified Model could improve accuracy in forecasting flood-producing thunderstorms. As Nigel explains, "Previously, this kind of research wasn't possible. It was only when the 'new dynamics' version of the Unified Model was developed that we were able to run simulations at such high resolutions."

The projects did show that a 1 to 1.5 km model could predict heavy or extreme rainfall events – but it was also clear that, paradoxically, the higher the resolution, the more room for uncertainty. So, as a solution, Nigel and his team turned to ensemble forecasting – using multiple forecasts instead of just one to assess certainty.

"We have our state of the art kilometre-scale models now, and they're incredibly realistic. The reason we need an ensemble is that the local fine-scale weather we now represent is more chaotic. Any errors in the forecast – even small ones – will grow. If we run an ensemble, we've got several shots at it. It gives an indication of the areas most at risk – so we can provide more reliable and useful weather warnings."

Breaking new ground

Nigel continues to work on Convective-Scale Ensembles at MetOffice@Reading, in collaboration with the Ensemble Forecasting Group in Exeter. The original aim was to demonstrate the potential value of a high-resolution (1.5 km) ensemble in forecasting the risk of hazardous local weather and to implement such an ensemble after 2012. However, things moved faster than planned.

"The results from initial case studies were very encouraging and it was clear this was something to implement as soon as possible. So a routinely running convective-scale ensemble system called MOGREPS-UK was set up by colleagues in Exeter in time for the Olympics."

There are more exciting developments to come in high-resolution ensemble and probabilistic forecasting. "The whole project is becoming even more collaborative, with researchers at Reading and other universities, as well as national meteorological services all working on the same area."

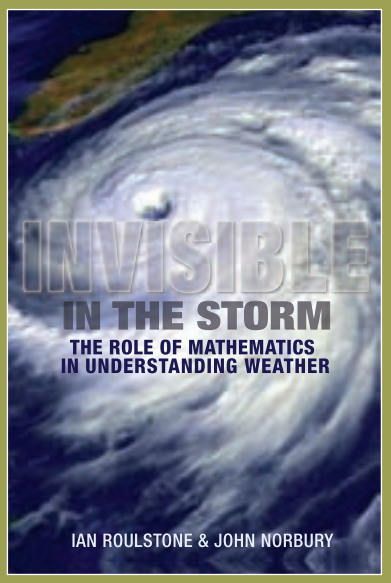
A lifelong passion

Weather has fascinated Nigel since he was a child. After completing a physics and meteorology degree at the University of Reading, he worked for a private forecasting company and joined the Met Office in 1989. His work has encompassed everything from quality control of satellite observations, to studying mid-latitude cyclones, fronts and thunderstorms, and developing new verification measures.

"It's nice to be able to discover something new about how the atmosphere works. I get a kick out of trying out new ideas and developing things that haven't been done before. That's particularly worthwhile if it leads to improvement in our forecast capability."

The role of maths in weather and climate prediction

In their new book, *'Invisible in the Storm: The Role of Mathematics in Understanding Weather'*, mathematicians Ian Roulstone (University of Surrey) and John Norbury (University of Oxford) explore how mathematics and meteorology come together to improve weather and climate prediction. Here they share their insight into maths, numerical weather prediction and climate models.



In 1904, the Norwegian physicist Vilhelm Bjerknes published a short paper entitled Weather Forecasting as a Problem in Mechanics and Physics, which heralded the beginning of a new era in meteorology and weather prediction. Bjerknes described a vision in which the laws of physics, and the equations that encapsulate them, were to become the cornerstone of a rational approach to forecasting. His ideas became the foundation of modern weather and climate prediction.

We had to wait nearly half a century before modern electronic computing made Bjerknes' vision a realistic prospect, and Vilhelm lived just long enough to see the beginnings of numerical weather prediction. But how would Bjerknes react if he could see a modern forecasting office? The breathtaking pace in the development of computers, satellites and associated technology such as weather radar, enable us to monitor weather around the world 24/7. Since the 1950s these developments have improved the accuracy of weather forecasts. It would have been impossible for Bjerknes to anticipate such progress, and he would be astonished at what is now at the disposal of forecasters. But he might well ask if we get caught out by the occasional storm that wasn't predicted – and Bjerknes would almost certainly anticipate an affirmative answer.

So why do forecasters, over a century after Bjerknes' landmark paper, still find some situations particularly problematic? Today, as a matter of routine, we calculate subtle changes in the basic variables – wind speed and direction, temperature, pressure, density and humidity – at millions of data points in our atmosphere, using seven basic equations at each data point. This amounts to solving tens of millions of equations. Yet we can solve these equations in minutes, because we have computers capable of over one thousand billion calculations per second (a measure we call a petaflop), and databases hold information in multiple petabytes. However, lurking in the fundamental equations is mathematics that makes forecasting so difficult, and makes weather so interesting. And Bjerknes understood the maths.

Behind the physics of the atmosphere is a phenomenon that challenges even the most powerful supercomputer simulations we use in forecasting today, and it will continue to challenge us in the future. It is called nonlinearity. This means that 'cause and effect' relationships between the basic variables become ferociously complex. We are familiar with the notion of chaos – that small changes in one variable can have a huge impact on other variables, as epitomised by Edward Lorenz in his famous allegory we know as the butterfly effect. Chaos in the weather is a consequence of the nonlinearity in the equations.

But while there's a devil in the mathematical detail, maths also offers us ways of dealing with these problems so that we can make useful predictions, and continue to improve our forecasts, even in the presence of chaos. By combining the basic variables we can understand what orchestrates the myriad of local interactions to produce coherent, swirling, cyclones, with warm and cold fronts. For example, by combining equations describing heat and moisture with equations governing the wind and pressure, we can form a new variable called potential vorticity, or 'PV'. Vorticity is a measure of swirling motion. PV actually helps us to identify key mechanisms that are responsible for the development, the intensity, and the motion of weather systems – including superstorms such as Hurricane Sandy – because it encapsulates over-arching physical principles that control the otherwise complicated 'cause and effect' relationships. These principles enable us to decide what is predictable amid the detailed interactions.

Much of the current research within the Met Office and universities is devoted to improving the numerical methods that lie at the heart of the gargantuan computer models. As more detail is incorporated into the simulations, so it becomes even more important to represent the over-arching principles that govern large-scale weather patterns even more accurately. Amazingly, the mathematics describing PV was developed initially by Vilhelm Bjerknes over a hundred years ago.

As we note in our new book, *Invisible in the Storm*, "There are many detailed interactions and there are degrees of unpredictability. But there are also many stabilizing mechanisms and, most importantly, for understanding and prediction, there is the maths to quantify the rules."

➔ For a chance to win a copy of Invisible in the Storm, simply fill in and return the reply card opposite.

Ben Fogle is a busy individual. Adventurer, presenter, journalist – since appearing in the reality TV show Castaway in 2000, his career has gone stratospheric. Today, he has a CV, and workload, that makes dizzying reading. But any career forged in the outdoors will, at some point, face the challenge of the weather – even if that means dealing with conditions that are simply too good.

Renaissance man

It's rare for people in the UK to be blighted by particularly clement weather – but this is exactly what Ben had to deal with when filming a new documentary called Harbour Lives. The series examines the lives of people living and working in and around Poole Harbour (Europe's largest natural harbour), from the wealthy residents of Sandbanks, to the fisherman that do battle with the sea every day.

"I met several fishermen who told of near death experiences when they were caught in storms and dragged overboard in nets. Unfortunately, our filming coincided with a heatwave, so people watching the show might think they lead a pretty idyllic life. The reality is very different."

A series about a harbour town on the Dorset coast may seem like quite a departure for a man who cemented his place in the spotlight through intrepid adventures. After all, Ben can lay claim to having rowed across the Atlantic, trekked to the South Pole and even cycled from Edinburgh to London in a rickshaw. But more so than the vast majority of celebrities, his career has been incredibly varied to date. So alongside these demanding – and sometimes perilous – adventures he has also presented Crufts, One Man and his Dog and Countryfile, to name just a few.

But if there is a defining theme in Ben's work it's the link with nature, the outdoors and, of course, the elements. This made him the perfect choice of presenter for a recent Sky Atlantic programme, Storm City.

This four-part series examines the science behind some of the most destructive forces of nature including tornadoes, hurricanes – as well as more geological phenomenon such as earthquakes. As part of the filming, Ben witnessed first-hand the aftermath of several natural weather events – an experience that made a big impact on him.

"It was unbelievable to see what the power of something like a tornado can do. I saw a ten-plus storey hospital in the US that had been flattened. It was one of the most shocking things I have ever seen. We also saw people's lives that had been completely and utterly transformed by the weather."

Extreme measures

Ben is no stranger to extreme weather himself and says that, "Like a lot of Brits [he] enjoys hot climates." However, this was pushed to the limits on a recent trip to the 'Empty Quarter' of the Arabian Peninsula where he completed a recreation of a 1940's expedition in average daytime temperatures of 48 degrees centigrade. It was, he described it, the "hottest place I've ever been." On the same trip, Ben travelled to the coast of Oman during the rainy season, where he found locals showing the same giddy excitement for rain as so many people in the UK do for sun.

"It was amazing to see people in their droves racing towards the rain, scared they were going to miss it. I think it shows that we all want what we don't have."

From deserts to ice caps and jungles to pounding seas, Ben has had to cope with almost every condition on earth.

"I've learned the hard way. You plan around weather windows but it seems that every trip I've done coincided with the hottest, the windiest or the wettest weather. For example, when we rowed the Atlantic, it was one of the stormiest seasons on record."

So what keeps him going when things get tough? "I describe myself as a have-a-go person. It doesn't matter if I'm not the fastest or quickest as long as I've seen it through to the end."

Although the date hasn't yet been set, Ben is already in training for his next big adventure – a cross-Atlantic swim. If that doesn't test his determination then nothing will.

Wow!

Since its launch in June 2011, the Weather Observations Website (WOW) has received more than 100 million weather observations from weather enthusiasts all over the world.

Part of the website is a photo gallery of images sent in by observers. This striking black and white image of cumulonimbus was taken by Rob Powell from Stonehaven beach on Scotland's northeast coast.

WOW was developed by the Met Office with support from the Royal Meteorological Society and the Department for Education. The site provides an online hub for UK weather observations, which helps educate children about weather and encourages further growth in the UK's amateur weather observing community.

Despite its UK focus, WOW has global coverage and has attracted visits from weather enthusiasts in more than 170 countries.

http://wow.metoffice.gov.uk/