Science & Technology Committee: Written evidence

Science in the Met Office

This volume contains the written evidence accepted by the Science & Technology Committee for the Science in the Met Office inquiry.

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1 Introduction

1.1 The aim of the Met Office is to provide the UK and its citizens with the best weather and climate service in the world, measured by the usefulness and quality of its products and services and the value for money it delivers. The quality of its services has a direct impact on public safety and national security and resilience.

1.2 International benchmarking of global weather forecasting skill is supported through the UN World Meteorological Organization (WMO). A range of metrics are used which all show that the Met Office is consistently within the top three centres globally. This position has been achieved through sustained investment in research, observations and supercomputing.

1.3 Underpinning this reputation is the delivery of outstanding science and the reliability and continuous improvement of Met Office products and services. This reputation is essential to building UK and international partnerships; which deliver significant cost benefits and enable the Met Office to achieve far more for its customers than it could on its own.

1.4 Weather and climate science is used by Government, emergency responders, commercial companies and the public to inform decisions. It is used as military intelligence to support strategic and tactical operations and by others to manage and mitigate the impacts of natural disasters, at home and abroad. It provides the scientific evidence base for Government policymaking on climate mitigation and adaptation, and informs major national infrastructure projects. Increasingly, it is seen as vital for helping society to be better prepared and become more resilient in a world becoming more exposed and vulnerable to weather and climate extremes.

1.5 Commercial companies depend on weather and climate information to inform a growing range of business and operating decisions - ensuring aircraft have enough fuel to fly safely, informing risk assessments by insurance companies, and supporting energy demand calculations by utility companies.

1.6 The Met Office is unique, globally, in providing both weather and climate advice from a single organisation using the same computer model and drawing from the same scientific, technical and delivery infrastructure. Other countries express a wish to emulate this approach.

1.7 The weather and climate services the Government and public rely on, sit at the cutting edge of the science. The delay between scientific advance and the help it offers, through improved services or policy advice, is very short indeed. The Met Office science programme is therefore very directed and has a high pull through of science into services. In 2010/11, 80% of weather

research is estimated to have been used in forecasting with 50% having significant and positive impacts on weather forecast scores.

1.8 The quality of and advances in Met Office science and services depends critically on reliable observations and continuing access to significant supercomputing resources that are robust and available 24/7.

1.9 The impact of weather and climate on public safety[1], national security[2] and the global economy[3] makes it essential that the Met Office remains at the cutting edge of understanding, modelling and predicting the atmosphere, oceans and full climate system. The Met Office Science Strategy is designed to maintain that position.

1.10 A 2007 assessment[4] of the Public Weather Service's (PWS) contribution to the UK economy concluded that:

a. PWS delivers an exceptional return on investment – as a conservative estimate it delivers value of £7.40 for every £1 invested;

b. PWS saves lives – hundreds of lives are saved each year[5] as a result of the services provided;

c. PWS output is world class – the international meteorological community endorses this quality with numerous other meteorological services licensing the Met Office forecast model;

d. greater benefit could be achieved with even more accuracy; the more accurate weather forecasts are, the more likely people are to take action.

1.11 In 2010 the GCSA led a review of Government needs for climate science services over the next decade, and how these can be met[6]. Initial consideration of this was presented in Sir John Lawton's 2009 review[7]. Both reports concluded "*the Met Office Hadley Centre provides essential and world-leading climate modelling services to Government, and that it is uniquely placed to do so. It represents a critical national capability, with a central role of meeting the*

[1] For example the floods of summer 2007 resulted in 13 deaths, 7000 people to be rescued by emergency services and flooding in 55,000 properties.
[2] The National Security Strategy describes a major accident of natural hazard which requires a national response as a Tier 1 risk and states that the effects of climate change are likely to become increasingly significant as a risk multiplier, exacerbating existing tensions around the world.
[3] For example, it is estimated that severe winter weather in 2010/11 reduced the UK's GDP by 5%, with travel disruption alone costing the UK economy £280 million per day
[4] The Public weather Service's contribution to the UK economy: http://www.metoffice.gov.uk/about-us/what/pws/value
[5] For example due to initiation of safety policies in industry, improvement of road, flight and marine safety and through the preparation and practice of contingency procedures for national emergencies
[6] http://www.bis.gov.uk/assets/bispartners/goscience/docs/r/10-1290-review-of-climate-science-advice.pdf
[7] http://www.bis.gov.uk/assets/bispartners/goscience/docs/s/2009-sir-john-lawton-review-report.pdf

Government's requirements for climate evidence and advice." Both reviews recognise the synergy and efficiency achieved through shared research, infrastructure and capability within the Met Office. In 2009 this was estimated to be worth more than £12M per annum.

1.12 Sustained investment in research and infrastructure delivers improvements in forecast accuracy, reliability and utility at all lead times and enables even greater economic value to be realised. The Met Office Science Strategy is designed to deliver those improvements and to support and enhance the full range of services the Met Office provides, including the PWS.

1.13 The Met Office believes there is an opportunity to deliver greater economic benefit from the UK's investment in environmental science. Partnership and collaboration with others actively undertaking research in related branches of environmental science will stimulate innovation, enabling improved and more efficient ways of delivering existing services . More importantly it enables the creation of new services designed to address a much broader range of natural hazards, and help the private sector exploit environmental information to advantage. Achieving this goal requires multi-disciplinary research, with scientific experts working with public and private sector partners to co-develop products and services.

2 How effectively is the Met Office fulfilling its PWS remit?

What is the Public Weather Service?

2.1 The Public Weather Service accounted for 48% of Met Office revenue in 2010/11[8]. It buys:

a. the support, maintenance and operation of the UK's observational network;

b. scientific research and development to deliver improved accuracy, longer lead time and more relevant free at point of use weather forecasts and warnings for the public and civil contingency community;

c. the real time 24/7 human analysis, interpretation and communication of observations and computer model outputs to generate weather forecasts;

d. the support, maintenance and operation of the supercomputer and underpinning IT infrastructure required to produce and disseminate the PWS forecasts for the public.

e. international commitments;

f. the National Meteorological Library and Archive.

[8] For reference in 2010/11 the Met Office turnover was £196.1M of which 47.7% was for the PWS, 17.5% from services to MoD, 18.2% for other services to Government – primarily climate science for DECC and Defra and 16.4% was for commercial services. (Met Office Annual Report and Accounts 2010/11 http://www.metoffice.gov.uk/learning/library/publications/corporate)

2.2 The Public Weather Service Customer Group (PWSCG) acts as customer for the PWS on behalf of government (including the devolved administrations and local government) and the UK public. It defines the outputs of the PWS, monitors the delivery of the PWS and where necessary challenges the Met Office and calls it to account. The PWSCG provides an independent and impartial body to balance the tension of public and responders' requirements, the funding available and current Met Office capability. The independent Chair of the Group is appointed by, and reports to, the Minister responsible for overseeing the customer function of the Met Office (Rt Hon David Willetts MP). Each year the PWSCG provides an Annual Report outlining how the Met Office has fulfilled its remit[9].

2.3 Warnings of hazardous or disruptive weather are provided to the public and Category 1 and 2 emergency responders through the National Severe Weather Warning Service (NSWWS). Further support is provided to local resilience fora, the Scottish Government Resilience Room (SGoRR), COBR and NSC (THRC)[10] through a regional network of Public Weather Service Advisors. The Advisors work with responders to anticipate and mitigate the impacts of severe weather. In other emergency situations, at home or abroad, where weather intensifies the impacts, hamper the emergency response or slow recovery, the Advisors work with the teams involved. In the last year the Met Office has advised on:

a. Grimsvötn volcanic eruption

b. Fukushima nuclear disaster

c. Winter weather (Nov-Feb)

d. Libyan crisis

e. August riots

f. Royal wedding

g. Pope's visit

2.4 Warnings and forecasts are communicated through the Met Office website, its iPhone app, Weather Widget and through television and radio broadcasts.

[9] 2010-11 report: http://www.metoffice.gov.uk/media/pdf/m/5/PWSCG_Annual_Report.pdf
2009-10 report: http://www.metoffice.gov.uk/media/pdf/1/c/PWSCG_Annual_Report_2009-10.pdf
[10] National Security Council (Threats, Hazards, Resilience and Contingency)

a. During the cold weather of December 2010 the Met Office website received 40 million visits (12.9 million unique visitors) with 3.6 million visits on just one day.

b. Since its launch in January 2010, the Met Office iPhone app has been downloaded more than 1.8 million times, and is regularly the top free weather application.

c. The Met Office Weather Widget is currently embedded in over 2000 other websites.

2.5 Information on the UK's climate is also made available on the Met Office website[11] including written summaries, maps of monthly average temperatures and rainfall, anomalies from long term averages, values for specific locations and records relating to extremes of weather for the UK, England, Wales, Scotland and Northern Ireland.

2.6 Paper based records of the nation's climate are held in the National Meteorological Library and Archive which is open to the public and maintains a comprehensive library collection for general, historical and academic use. The Library and Archive acts as a registered Place of Deposit (under the public records act) for paper-based meteorological records and physical artefacts related to meteorology. There are archives located in Exeter (for England and Wales), Edinburgh and Belfast.

Public awareness and satisfaction

2.7 The PWSCG routinely undertakes public perception surveys to assess satisfaction with the forecast and warnings service. These results are summarised in the PWSCG Annual Report and published on the Met Office website[12]:

a. the November 2010 survey indicated that nine out of ten people found weather forecasts useful and just over three quarters found them accurate;

b. warnings of snow and gales are generally considered more useful than warnings of heavy rain;

c. averaged over the 8 surveys conducted following severe weather events in 2010/11, 77% of respondents had seen or heard the warning and of these 89% of respondents found the warnings very or fairly useful;

d. three surveys were carried out related to warnings for snow in Nov-Dec 2010 (27 Nov, 1 Dec, 13 Dec). In all three cases more than 90% of respondents found the warnings 'very' or 'fairly' useful.

2.8 Surveys of emergency responders are conducted routinely to assess their satisfaction with the PWS and warnings service. The Feb-March 2011 survey indicated:

[11] http://www.metoffice.gov.uk/weather/uk/climate.html
[12] www.metoffice.gov.uk/about-us/who/accuracy/your-say

a. satisfaction with the PWS was extremely high with 97% of responders saying they are satisfied and almost three quarters (73%) saying they are ‘very satisfied’. This has increased markedly since 2008 when only 58% of responders were ‘very satisfied’;

b. 62% of responders were ‘very satisfied’ with the last weather warning received compared to 56% in 2008;

c. 90% of responders who have had contact with a PWS Advisor were ‘very satisfied’ with the service provided, compared to 86% in 2008.

Continuous improvement

2.9 The accuracy of Met Office forecasts are evaluated against observations on a daily basis. The PWSCG specify accuracy targets for forecasts of maximum and minimum temperatures, rain, sun, wind speed and wind direction. In 2010/11 all targets were met. As of August 2011, on average (over a 36-month period) the percentage of forecasts accurate to within $\pm$ 2 °C is:

a. 87.6% of maximum temperature forecasts on the day the forecast is issued (target for 2011/12 85%) and 78.5% of minimum temperature forecasts (target 76.5%);

b. 81.1% of maximum temperature forecasts on the second day of the forecast (target 79.5%) and 71.7% of minimum temperature forecasts (target 69.0%).

2.10 Improvements are possible by making forecasts more local. In 2010/11 PWSCG tasked the Met Office with increasing the number of UK locations for which it provides forecast from approx. 350 to approx. 5,000 updated hourly. This gives people local weather forecasts to help plan their activities.

2.11 Following the launch of 5,000 sites Mark Smith, Director of Bournemouth Tourism stated that “*These new forecasts from the Met Office communicate weather forecast information in clearer, more appropriate and user friendly ways that allow tourists and tourism operators to better plan activities. As weather is a key driver for tourists, I am sure that this improved communication will have a positive economic impact on our industry and will improve the overall quality of life for British residents through more productive use of their leisure time."*

2.12 Public consultation also indicated scope to improve how the National Severe Weather Warning Service is communicated, and the service was upgraded in March 2011. The main improvements are:

a. impact-based alerts and warnings are now based on both the expected weather conditions and the potential impact they may have, recognising that the same weather can have a

different impact in different parts of the UK, at different times of the year and depending on preceding conditions;

b. improved website display - making it easier for the public to find information relevant to them, assess the risk and the option to drill down to more detail;

c. easier to understand - warnings have been made simpler and clearer using less technical language and the categories of warnings have been simplified.

2.13 Increasingly, advice is based upon the outputs from multiple forecasts (ensemble modelling[13]) which enable customers and stakeholders to make properly informed decisions based on probabilities and levels of risk. From September 2011 the 5,000 site forecasts will include the probability of rain and in 2012 the Met Office will introduce an ensemble of short range forecasts using the very high resolution UK version of the forecasting system to support the Olympics.

3 Is the Met Office's Science Strategy 2010-15 robust and achievable and how will the strategy help to deliver a better service?

3.1 The Science Strategy drives improved capabilities and efficiencies through scientific and technical advancements, by delivering a highly coordinated programme of research and development across weather, climate and marine science. It sets the agenda to meet the challenge of maintaining the Met Office, and indeed the UK, as a world-leader in weather and climate prediction. It drives ongoing development and improvements to its range of services, to deliver more robust advice to end-users.

3.2 The Science Strategy builds on the strong scientific reputation of the Met Office. Its R&D programme has always been, and continues to be strongly directed to improving the quality of its weather forecasts and climate predictions to deliver greater benefits to the UK. This focus is regarded as a major factor in the success of the Met Office and in the world-leading status of the UK in weather and climate prediction.

3.3 The Science Strategy:

a. develops and exploits the significant synergies that exist in the science[14] and operational infrastructure[15] that underpin all Met Office services;

[13] Ensemble forecasting involves running multiple forecasts with slightly different initial conditions or modelling parameters to provide a probabilistic assessment of possible outcomes and risk

[14] The GCSA's report states "*The case for the Hadley Centre's continued integration in the Met Office is compelling, given the strong synergies with the public weather service and modelling, and the shared infrastructure and common capabilities which link to this. Significant efficiencies arise from this relationship. It will be important to recognise this synergy and how it can be continued in any discussions about business models for*

b. enables the Met Office to respond to the increasing demand for seamless prediction systems to support planning and adaptation decisions across all timescales from hours to decades;

c. breaks down the traditional barriers between weather and climate, which are widely recognised as hampering progress[16];

d. enables the Met Office to respond to, anticipate and shape the changing requirements of current and future stakeholders and customers;

e. recognises and incorporates the excellence of atmospheric and climate science within UK academia and NERC, and in leading international institutions and forecasting agencies.

3.4 The Science Strategy focuses Met Office research around four major cross-cutting science challenges which are designed to drive significant improvements in capability:

a. longer lead time and more accurate local forecasts and warnings of severe weather, including extreme rainfall and flooding, enabling Government, emergency responders and other organisations to be better prepared and more resilient;

b. significant improvements in assessments of future changes in weather patterns, especially the intensity and frequency of severe weather events, to enable more robust planning and decision-making around infrastructure investments to adapt to climate change;

c. more confident regional predictions of changes in the global water cycle to underpin assessments of future challenges to water availability and global food security;

d. delivery of a comprehensive monthly to decadal forecasting service to enable improved operational planning across all sectors that are vulnerable to variations in weather and climate, especially in the developing world;

e. ensuring that Government receives the best possible scientific evidence on potential risks of dangerous climate change by maintaining a strong base in climate change detection and attribution, and by developing a world-leading Earth system model;

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the Met Office as a whole." Whilst the Lawton report states that "The Met Office Hadley Centre estimates that climate model development may benefit from the Met Office's research and development programme to the tune of more than £12M per annum".

[15] Including 24x7 supercomputing, observations, modelling and forecasting capabilities

[16] E.g. Hurrell et al. (2009), A Unified Modeling Approach to Climate System Prediction, published in Bulletin American Meteorological Society, doi: 10.1175/2009BAMS2752.1 http://journals.ametsoc.org/doi/abs/10.1175/2009BAMS2752.1

f. underpinning Government policies on climate change mitigation with robust scientific assessment of their impacts at both the global and regional level.

3.5 Two independent groups review the integrity of Met Office science ensuring it is fit for purpose:

a. The Met Office Scientific Advisory Council (MOSAC) reviews PWS funded science. It is chaired by Professor Sir Brian Hoskins FRS, who is also a Non-Executive Director on the Met Office Board. It comprises leading scientists from UK academia and research heads from leading National Meteorological Services. The Committee meets annually to review progress, ensure research plans address future customer requirements and monitor the effectiveness of collaborations. The Chief Scientist is required to respond to the Chairman's report which is presented both to the PWSCG and the Board.

b. Climate research is reviewed by the Hadley Centre Scientific Review Group (SRG), jointly owned DECC and Defra and comprising UK and international climate science experts. Membership of the Group is determined by DECC and the current Chair is Professor John Pyle FRS. The Chair of the SRG also sits on MOSAC to ensure cohesion across the entirety of the Met Office scientific research. The Group meets annually and operates in a similar manner to MOSAC.

3.6 In 2009 MOSAC reviewed the Science Strategy. The Chair's report stated "*The Met Office is in a unique position to react to the move towards considering the seamless nature of the weather-climate prediction problem and produce a range of services based on predictions for time-periods from hours to a century…… the guiding principle of seamless prediction was very strongly supported. The benefits to the Met Office in terms of both its unity and the mobility around it of its scientists are also significant."*

3.7 A year later the 2010 MOSAC Chair's report stated "*It is important to keep in mind the full range of challenging and important prediction problems included in the new seamless science perspective: from kilometre scale weather forecasting on hourly time-scales, through the weeks to decades time-scales, and on to century time-scale Earth System/climate projection. The range of talks presented and the discussions stimulated by them showed that the approach to R&D based on the seamless nature of the weather-climate prediction problem is already well embedded and the advantages are starting to be realised.*"

3.8 The Science Strategy Implementation Plan has since been developed and sets out the target vision, timeline and actions required to deliver the Strategy. Considerable progress has already been made by the Met Office, and partners, in implementing the Strategy and maintaining and building its scientific quality and reputation across its weather and climate science. In 2010, MOSAC "*considered that remarkable progress had been made in developing and implementing*

the new organisational structure" and "*recognised the high quality of the science presented to it, the relevance of this science to customer requirements, and the enthusiasm of all those who presented and discussed it*".

3.9 Met Office research is now communicated to a general audience through the Met Office website[17], which describes the science and profiles Met Office scientists.

3.10 At the core of the Science Strategy is the development of much stronger science partnerships. The Met Office recognises that the increasing breadth and depth of the science means that partnering with the best scientists in the UK and abroad will be essential for delivering the range of weather and climate services that will be required in the future. With its expertise in bringing science to market the Met Office has a key role to play in integrating and facilitating research.

3.11 In 2010/11 the Met Office engaged in 165 collaborative science projects, estimated to be worth over £15M in additional resource, equivalent to a third of the Government-funded Met Office science budget. Formal structures are being established to bring partners' knowledge and expertise through into improved science and services. A new programme on Science Partnerships as outlined in the Science Strategy has been established to coordinate and develop a range of directed collaborative activities, which include:

a. realising the benefits of the shared dependence on the performance of the Met Office Unified Model (UM) with our international partners in National Met Services[18.] For example, a shared operational seasonal forecasting capability has been agreed with South Korea, which will enable the Met Office to employ a model resolution and ensemble size that would not be possible with UK supercomputing resources alone;

b. developing the Met Office/NERC Joint Weather and Climate Research Programme (JWCRP) to ensure that the UK's national capability in weather and climate science is sustained. This includes joint research strategies (e.g. UK Earth System Modelling Strategy) and the development and maintenance of major investments in joint research facilities (e.g. BAe146 research aircraft). A jointly funded programme, the first of its kind, has been established on the Development of Next Generation Computer Codes. The shared supercomputing service (MONSooN[19]) to support JWCRP collaborative projects has proved highly successful, currently supporting 15 projects involving more than150 scientists. Utilisation is running at 93%;

[17] http://www.metoffice.gov.uk/research
[18] Current partners are Norway, Australia, South Korea, South Africa, India, New Zealand and the US Air Force.
[19] MONSooN provides a supercomputing platform for collaboration with NERC http://www.metoffice.gov.uk/research/collaboration/jwcrp/monsoon-hpc

c. launching the Met Office Academic Partnership in 2010 to create a cluster of research excellence with the universities of Exeter, Leeds and Reading. Joint Chairs have been funded at each university and joint research plans are in development. In 2010/11 the partnership covered 41 projects worth £1.8M in additional gearing;

d. supporting 72 industrial PhD studentships across 15 UK universities.

Further development of the Science Partnerships programme is expected to deliver increasing levels of gearing from national and international collaborations.

3.12 The Science Strategy also addresses the challenges of maintaining and developing the research infrastructure, along with a world-class scientific work-force, required to deliver a world-class service.

3.13 Supercomputing is critical to delivering the Science Strategy and a range of options are actively being pursued. This includes exploring international opportunities (e.g. in the USA and China) and engaging at a high level in European discussions around future supercomputing initiatives. With NERC, a major project has just been approved which will enable cutting edge research on high resolution climate modelling and scalability of computer codes to address future supercomputer architectures.

3.14 The 2010 GCSA review of Government's needs for Climate Science Service recommended that a step-change increase in supercomputing capacity would be required to most effectively meet the Government's key evidence and advice needs. More recently, the House of Commons Transport Select Committee stated that benefits would be realised if funding was made available for additional supercomputing resources. This would enable the latest scientific capability to be used to deliver scenarios of hazardous weather in the next 20-30 years to inform infrastructure investment decisions, and provide more robust monthly and seasonal forecasts.

3.15 The improvement in service quality delivered through achieving the Met Office Science Strategy will continue to be dictated by how effectively scientific advances are translated into operational capability and improved advice to stakeholders and customers. In 2009/10, 81% of weather research is estimated to have been used in forecasting improvements, with 49% having significant and positive impacts on the weather forecast. In 2010/11 these figures were 80% and 50% respectively.

4 What are the roles of the Met Office's Chief Scientific Advisor and its other senior scientists? How do they provide comprehensive and up-to-date scientific advice?

4.1 The Met Office does not have a Chief Scientific Advisor in the sense of Government Department Advisors. It has an Executive-level Chief Scientist who reports to the Met Office Chief Executive and Met Office Board. This is a 2* Senior Civil Service appointment.

4.2 The Met Office Chief Scientist has responsibility for leading and delivering the Met Office Science programme, consisting of 490 scientists and a budget of £44.6M. The Chief Scientist is responsible for setting the strategy, ensuring that the Met Office science programme drives improvements in the quality and reach of the full range of Met Office services, and that the scientific integrity of those services is of the highest standard.

4.3 As outlined in the Science Strategy, in 2010 the Chief Scientist brought together all Met Office science into a coherent programme, establishing a senior management structure and a single administration function. The Senior Management Team is constituted from the Deputy Directors of Foundation, Weather and Climate Science, along with the Heads of Science Administration and Science Partnerships. This has delivered a more flexible structure that enables the Met Office to respond more effectively to emerging issues and Government needs, and to re-prioritise its science and resources accordingly.

4.4 The Chief Scientist is Head of the Science Profession and oversees career development and teaching and learning opportunities. In September 2011 a formal programme of Continuing Professional Development opportunities was established.

4.5 The Chief Scientist and the senior staff ensure the Met Office delivers high quality and timely scientific advice by engaging pro-actively with government departments, industry and the public through a range of channels. Internal structures are in place to ensure that Government requests for advice are dealt with swiftly and that the appropriate scientists are engaged in the process. A senior-level Knowledge Integration post has been established to support DECC and Defra's needs for climate science advice. During hazardous weather, scientists work with PWS Advisors to ensure the advice provided is robust and scientifically sound.

4.6 The Chief Scientist works closely with the GCSA[20], providing advice and information across the range of Met Office science and services. She ensures that key expert scientists across the Met Office are engaged to support the Scientific Advisory Group for Emergencies (SAGE). Recent examples include representation at the SAGE during the Eyjafjallajökull eruption in 2010 and the Fukushima nuclear incident in 2011. The Met Office provided written and oral briefings to GCSA and Secretary of State for Transport during winter 2010 and the Grimsvötn 2011 eruption.

[20] 8 1:1s with Government Chief Scientific Adviser in 2010/11, plus 26 other meetings and events

4.7 The Chief Scientist regularly engages with a range of Chief Scientific Advisors[21] and hosts an increasing number of visits to the Met Office to promote in-depth discussions on specific policy needs. She fulfils high-profile public speaking engagements on weather and climate science, natural hazards and computational modelling. In December 2010, she gave the keynote Frontiers of Geophysics lecture at the American Geophysics Union.

4.8 The Chief Scientist is also instrumental in fostering new collaborations and ensuring effective alignment of research plans with our partners, particularly NERC, ECMWF, UM Partners and WCRP[22]. In 2010 she initiated a partnership with the US NOAA Space Weather Prediction Centre which has resulted in the delivery of operational space weather services in the UK.

4.9 The Chief Scientist and senior staff ensure that high quality, comprehensive and up-to-date advice is provided by maintaining a cutting-edge science base across all key areas, and working effectively with partners to deliver integrated knowledge and services. As part of this process, Met Office scientists engage in international programmes and publish in the top journals:

a. In 2010, Met Office scientists served on over 180 key national and international committees. These committees set research agendas, influence investment decisions and define the delivery of science to services.

b. In 2010, Met Office scientists authored 263 papers, 80% of which were co-authored with external partners. These scientists came from 441 different institutions across 44 different countries.

c. In November 2009, a survey published in The Times Higher Educational Supplement ranked the Met Office Hadley Centre as the world's leading geophysical institution, ahead of Harvard and Princeton, in terms of the influence of its peer reviewed publications. According to ISI Web of Knowledge, the Met Office impact factor ('h-index') of 123 for papers published since 1991 is higher than any other equivalent weather or climate research institute in Europe. A landmark was recently reached when the first Met Office-led paper exceeded 1000 citations.

d. The Met Office is providing 8 lead author or co-lead authors for the forthcoming IPCC 5th Assessment Report, which will draw heavily on Met Office climate research for its evidence.

5 How robust are the models used by the Met Office for weather forecasting, climate predictions, atmospheric dispersion and other activities?

[21] 16 1:1s in 2010/11, 25 external visitors to Exeter including 3 Secretaries of State and 6 Chief Scientific Advisors
[22] The Chief Scientist is a member of the NERC Council (Natural Environment Research Council), the ECMWF Science Advisory Council (European Centre for Medium-range Weather Forecasting), and the Joint Scientific Committee for WCRP (WMO/UNESCO/IOC/ICSU World Climate Research Programme)

Weather and climate models

5.1 The Met Office uses fundamentally the same model (Unified Model) across all timescales from daily weather forecasting to centennial climate change predictions, and for all space scales from the local to the global. For forecast lead times of a month or longer the Unified Model (UM) also includes a global ocean model; and for climate change projections, Earth system processes, such as an interactive carbon cycle and atmospheric composition, are included. This is a unique capability that no other National Meteorological Service or research institution possesses and it delivers significant scientific and operational efficiencies and benefits[23].

5.2 The bedrock of all Met Office modelling and prediction is the weather forecast version of the UM. Its performance is evaluated against observations on a daily basis in weather forecasting mode and its performance monitored and benchmarked against other world-leading models.

5.3 To deliver much finer scale forecasts over the UK, the Met Office uses a system of nested models. In 2009 it introduced a 1.5km resolution model over the UK providing a step change in capability. This made it possible to issue warnings of the 2009 Cumbrian floods 48 hours in advance, enabling much greater preparedness than would previously have been possible. The utility of this model in providing local information on the potential impacts of climate change is being explored.

5.4 Whilst accuracy is clearly important, an operational weather forecast model also has to be robust, run on secure, resilient infrastructure and able to generate outputs fast enough for them to be useful. Typically the delay between the latest observation used in the model and a customer receiving a global forecast has to be less than eighty minutes for it to be useful. This places costs upon an operational centre such as the Met Office and constraints on the formulation of its weather forecast model.

5.5 The skill of Met Office global weather forecast model has improved systematically (Figure1), with a rate of increase in skill of 1 day per decade. This means that a 3-day forecast today is as skilful as a 1-day forecast was 20 years ago. This increase in skill is attributed to more sophisticated atmospheric physics, higher model resolution and more comprehensive observations, especially from meteorological satellites.

5.6 International benchmarking of the performance of global numerical weather prediction systems is supported through the WMO. A range of metrics are used and all show that the Met Office is consistently within the top 3 centres internationally – an example is shown in Figure 2.

[23] In 2009 it was estimated that combining weather and climate prediction in the Met Office saved approximately £12M per annum.

5.7 Similar metrics are not yet available for longer range forecasts. This is partly because these forecasts are probabilistic in nature and appropriate methodologies do not yet exist, and partly because verification statistics are much more limited due to the short length of the observational base, especially in the ocean. The quality of its performance against other centres is assured by including the UM in all model comparisons and in the European Seasonal to Inter-annual Prediction (EUROSIP) ensemble of models, and reinforced by its use in other countries (e.g. Australia and South Korea) as the basis for their own seasonal forecasting systems. The Met Office is one of twelve centres which have been designated by WMO as Global Producing Centres of long-range forecasts.

5.8 The Met Office also participates in objective comparisons of climate model performance, which have been integral to the international community since the first climate models were built. A 2008 paper[24] assessed the realism of such models in simulating the mean current climate using data from the Coupled Model Intercomparison Projects (CMIP) which underpin the Intergovernmental Panel on Climate Change (IPCC) Assessment Reports. It indicates that the skill of all climate models increase notably with time and that the state of the art climate version of the UM was ranked in the top two models for all three CMIP projects[25].

5.9 The robustness and skill of the UM-based forecasting system is evidenced by the increasing uptake by other National Met Services. The Met Office licences the UM to other National Met Services for operational use; the licence fee is waived if research effort is provided in kind to help improve the model. Current operational users are: Norway, Australia, South Korea, South Africa, India, New Zealand and the US Air Force. This international UM partnership is becoming increasingly important as the operational expertise of the participating members grows, and the model is tested against weather conditions across the world.

Dispersion modelling

5.10 During volcanic eruptions, pollution events and other scenarios when potentially hazardous material is emitted into the atmosphere, the Met Office uses its NAME[26] model to predict how material will be dispersed in the atmosphere and deposited on the ground. NAME uses the weather forecast data generated by the UM, together with estimates of the amount of material emitted, the height to which it is emitted and the size of the particles to estimate the distribution of material. Examples of events in which NAME has been used include:

[24] Reichler and Kim (2008) How well do coupled models simulate today's climate? Bulletin of American Meteorology Society, 89, 303-311– CMIP 1 (1995) and CMIP 2 (1997) were used in the 3rd IPCC assessment and the UM was ranked first for both intercomparisons, and CMIP-3 (2004) in which the UM was ranked 2nd was used in the 4th IPCC assessment.
[25] The current generation of climate models will form CMIP-5, to be reported in the forthcoming IPCC 5th Assessment.
[26] Numerical Atmospheric-dispersion Modelling Environment model (NAME)

a. Pollution resulting from the Kuwaiti oil fires (First Gulf War);

b. 2005 Buncefield oil storage depot incident;

c. 2001 and 2007 Foot and Mouth disease outbreaks;

d. 2008 Bluetongue outbreak over Europe[27];

e. 2010 and 2011 volcanic eruptions (Eyjafjallajökull, Grimsvötn, Chile, Eritrea);

f. 2011 Fukushima nuclear incident

5.11 It is much harder to verify the accuracy of a dispersion model, because dispersion events occur infrequently and it can be difficult to obtain reliable, quantifiable observations of the distribution and concentration of material. Confidence in the Met Office NAME dispersion model has therefore been established over time based upon subjective comparison of predicted spread of material and observations of the extent of the spread and engagement in intercomparison exercises. These, combined with the knowledge that the input meteorological forecast data are amongst the best in the world, have helped to generate confidence in the model and in the forecasts it provides.

5.12 The 2010 eruption of Eyjafjallajökull sparked considerable interest in and scrutiny of NAME. Since this event a number of papers have been published in the peer reviewed literature that demonstrate the capability of NAME and the potential for further improvements. The Civil Aviation Authority also asked Professor David Fowler FRS to conduct an independent review of the model which concluded that "*the NAME model represents a state of the art dispersion model…The presence of a globally leading UK-based team dedicated to the development and application of a state of the art dispersion model and its application using a state of the art NWP model is considered a high strategic priority for both the development of the science and its practical application to a wide range of scientific issues*".

[27] A report by DTZ http://www.iah.ac.uk/ecosoc/docs/Blue-Tongue-case-study.pdf estimated that by preventing a major Bluetongue outbreak from affecting the UK's agricultural sector, the Institute for Animal Health and its partners (which include the Met Office) contribute to protect British farmers from a potential £485m loss in their annual income as well as to protect 10,000 jobs throughout the UK's economy that would otherwise be lost.

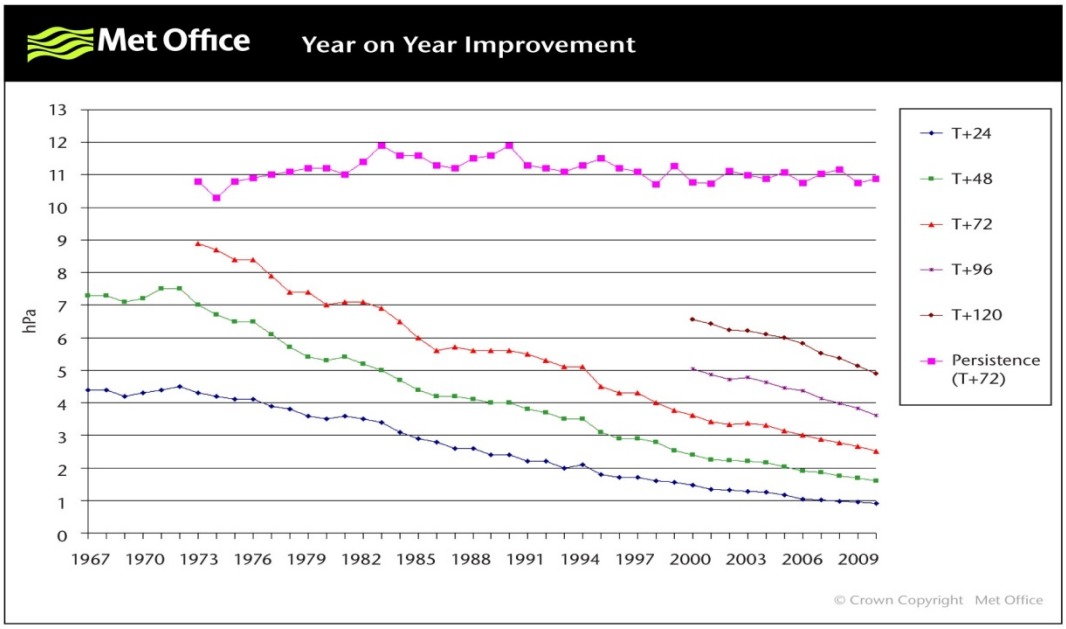


***Figure 1**: 40 year timeseries of Met Office weather forecast skill for surface pressure across the North Atlantic region for forecast lead times of 1 day (T+24hrs) up to 5 days (T+12hrs0), and compared with persistence – forecasting the weather will be the same tomorrow as it is today.*

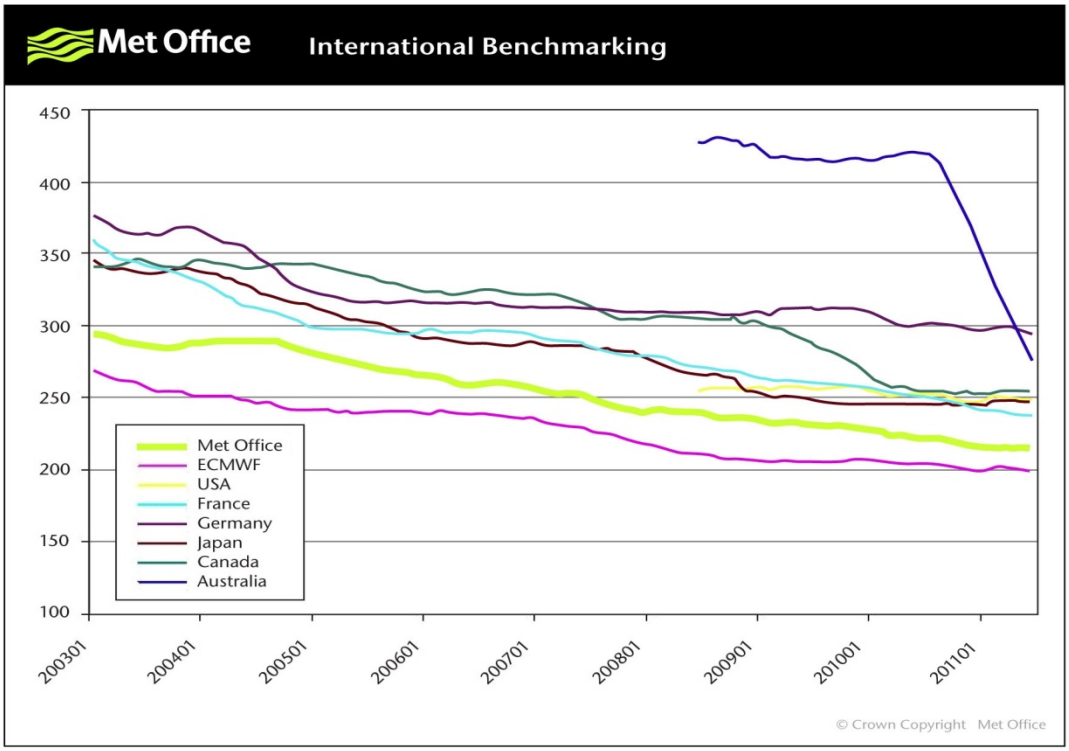


***Figure 2**: 12-month running mean root mean square error of 3-day forecast of Northern Hemisphere Mean Sea Level Pressure in Pascals. The lower the statistic, the better the forecast. ECMWF has the lowest error throughout. However, this is offset by the additional time available to ECMWF to produce the forecast. Met Office forecasts are in second place throughout, and have converged on the ECMWF accuracy in the past year or so. The dramatic improvement in the Australian scores over the past year reflects the implementation of the Met Office Unified Model (the gradual improvement is due to the use of a 12-month running mean score).*

6 How effectively does the Met Office coordinate its activities with government departments, non-departmental public bodies, the UK research base and its international counterparts?

6.1 As a Trading Fund the Met Office needs to constantly prove the value of its services to customers in both the public and private sector. There is therefore a permanent, constructive tension that encourages understanding of need, realisation of benefit and continuous improvement and innovation. Moreover, given that the Met Office and its services are always in the public eye there is active scrutiny.

6.2 The Director of Government Business is responsible for ensuring Met Office delivers products and services contracted by Government departments and NPDBs, including the PWS and for seeking opportunities to help Government meet its policy objectives through effective use of Met Office science and services. All customers have service level agreements with negotiated delivery schedules.

Coordination of activities with the research base

6.3 The Science Strategy recognises the importance of collaboration and partnerships. Activities with the UK and international research base are coordinated through the Science Partnerships Programme, overseen by the Chief Scientist and Head of Science Partnerships.

6.4 In 2010, Met Office scientists served on 39 committees related to the UK research base. The inclusion of representatives from the UK research community on MOSAC and the Met Office Hadley Centre SRG, along with Met Office Chief Scientist's membership of NERC Council, all help to ensure alignment of scientific strategy.

6.5 Met Office scientists serve on several steering groups for major NERC Research Programmes and increasingly act as key partners within those programmes. The JWCRP has been established to improve coordination and pull-through of NERC and Met Office science. There is also engagement with the EPSRC (e.g. flood protection) and BBSRC (e.g. animal health), and more recently with the MRC and the Wellcome Trust on weather, climate and health.

6.6 The Met Office engages strongly with EU Framework Programmes, in several instances providing leadership and management[28]. In 2010/11 the Met Office was involved in 22 FP7 projects with a value of £2.3M.

Coordinating international activities

6.7 The Head of International is responsible for coordinating activities with international counterparts. The effectiveness of these collaborations is assessed by targets set by the PWSCG for the

[28] For example, ENSEMBLES was a 5-year EU-funded integrated research project coordinated by the Met Office Hadley Centre to produce probabilistic projections of climate for Europe to help inform researchers, decision makers, business and the public.

achievement of international objectives. In 2010/11 the Met Office achieved all of its agreed international objectives.

6.8 International collaboration is essential to provide the observations on which the Met Office depends. Observations are exchanged in real time between the 189 states and territories who are members of the WMO. As a major node on the WMO Global Telecommunications Network the Met Office outputs 6,000,000 messages a day, equivalent to 70 messages a second.

6.9 Within Europe, collaboration also exists through the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) to fund and operate the constellation of meteorological satellites required to provide weather and climate-related satellite data, images and products – 24 hours a day, 365 days a year. Intergovernmental arrangements exist between Europe and other countries, including the US, for the real time exchange of weather and climate related satellite data.

6.10 In total the UK generates and owns less than 4% of the observational data on which it relies to deliver the PWS, less than 1% if satellite data are included.

6.11 As part of delivering the Public Weather Service the Met Office represents the UK at WMO, the European Centre for Medium Range Weather Forecasting (ECMWF) and EUMETSAT, with the aim of gaining best value for money from the UK's financial contributions. Membership also places obligations on the Met Office through the convention or treaty of the organisation including payment of the UK's financial contribution.

6.12 The views of the broader UK meteorological community are incorporated into the UK briefings for WMO Congress through a consultation meeting with the Met Office arranged through the Royal Meteorological Society. The UK Space Agency is invited to provide input to UK briefings ahead of EUMETSAT meetings.

6.13 The Met Office plays an active role in WMO and at the 2011 Congress meeting its Chief Executive was re-elected as a member of the Executive Council. He is Chair of the WMO Audit Committee and the Task Group on Continuous Improvement of Processes and Practices, which aims to reduce bureaucracy, improve efficiency, deliver better alignment to regional priorities, and seek partnership with other international organisations so that more money can be focussed on delivery of strategic initiatives and in particular capacity building in developing countries.

6.14 The Met Office also participates in a number of the WMO Commissions and Working Groups. It is currently vice chair of the Commission for Aeronautical Meteorology which aims to further the application of meteorology to aviation and works closely with ICAO and IATA. The Chief Scientist is a member of the Joint Scientific Committee which provides scientific guidance for the World Climate Research Programme (WCRP) and consists of 18 scientists selected by mutual

agreement between the three sponsoring organisations. The Met Office also chairs the Working Group on Numerical Experimentation (WGNE) which links weather and climate forecasting. Participation in these groups enables alignment of research plans, global collaboration between scientists and intercomparison of approaches and techniques, thus allowing best practice to be shared and improvements made in weather and climate prediction globally.

6.15 ECMWF and the Met Office work closely together in scientific research and model development to maintain their positions as leading global numerical weather prediction centres in the world. Each organisation is represented on the corresponding scientific review committees. For the last three years the Met Office has provided the Chair of the Technical Advisory Committee. The complementary remits of ECMWF and the Met Office are mutually beneficial, and can be shown to help drive excellence in Met Office science.

Coordination of activities with Government and NDPBs

6.16 The Flood Forecasting Centre (FFC), which has been operational since April 2009, co-locates meteorological and hydrological forecasters from the Met Office and Environment Agency in the Met Office 24/7 Operations Centre at Exeter[29]. The FFC was established in response to Sir Michael Pitt's independent review of the 2007 summer floods and has quickly become a key part of flood risk management in England and Wales through improved communication and consistency of weather and flood warnings.

6.17 The establishment of the FFC was an important first step in Government agencies working together to provide joined up scientific advice to Government and emergency responders. However, the Met Office recognises that the response to many other natural hazards requires a joined up approach from a range of Government agencies.

6.18 With this in mind the Met Office has been leading the creation of a Natural Hazards Partnership[30], with the support of the Cabinet Office Civil Contingency Secretariat. The Partnership is working to deliver cross-partner joined up services making use of shared data, skills and other assets with the aim of improving the communications, preparedness and response capabilities of the UK civil contingency community. The Met Office has also established a 24/7 Hazard Centre with underpinning infrastructure, systems and functionality for Met Office staff and partners to better manage major natural hazard related incidents and their impacts.

6.19 The DFID - Met Office Climate Science Research Partnership was established to work in consultation with African stakeholders to advance the scientific understanding of climate

[29] The FFC relocated from London to Exeter in 2011.
[30] Partners currently include: British Geological Survey (BGS), Centre for Ecology and Hydrology (CEH), Environment Agency (EA), Government Office for Science, Health Protection Agency, Met Office, National Centre for Atmospheric Science, National Oceanography Centre, Ordnance Survey and the UK Space Agency.

variability and change in Africa, to build capacity in Africa in climate science, and to bring new science into use.

Delivering greater benefit from the UK's investment in science

6.20 There are also significant opportunities for Met Office science to be used to support the global needs of the aid, disaster reduction and insurance communities. The Met Office is leading a consortium, comprising IBM, Imperial College and the Grantham Institute for Climate Change to establish a sustainable business model for the provision of value-added services, standards-compliant data, applications and models through an internet cloud hosted platform, known as the Open Platform. Funding for the initial 15 month project to prove the concept has been provided by the Technology Strategy Board.

6.21 A recent series of Open Platform workshops in the US received a very enthusiastic response. There is considerable interest from the World Bank whose primary objective is to ensure their funding decisions are based upon the best and most current projections of the climate. The Open Platform will facilitate this by providing easy access to both free and premium climate and environmental information via a self-sustaining marketplace which allows users to rate the quality of the data, products, applications and models.

6.22 The Met Office believes there is an opportunity to deliver greater economic benefit from the UK's investment in environmental science. Partnership and collaboration with others actively undertaking research in related branches of environmental science will stimulate innovation, enabling improved and more efficient ways of delivering existing services. More importantly it enables the creation of new services designed to address a much broader range of natural hazards, and help the private sector exploit environmental information to advantage. Achieving this goal requires multi-disciplinary research, with scientific experts working with public and private sector partners to co-develop products and services.

6.23 Most importantly this research needs to be pulled through to routinely deliver products and services. The Met Office has been working to establish an Environmental Science to Service Partnership with other government departments and agencies[31] to help realise this vision. The partnership is very much in its infancy, but if given support and encouragement, has the potential to deliver significant benefits, helping to support UK economic growth and continued excellence in environmental science.

[31] Partners include: Met Office, Defra, EA, NERC – represented by CEH and BGS and Ordnance Survey.

The Met Office

The Prime Minister announced on 18 July 2011 that responsibility for the Met Office would pass from the Ministry of Defence to the Department for Business, Innovation and Skills. The Met Office is a Trading Fund, operating independently of either Government Department. The Minister responsible for sponsorship of the Met Office is now Edward Davey MP; with the Rt Hon David Willetts MP responsible for the customer functions, including the customer for the Public Weather Service, receiving advice from the Public Weather Service Customer Group (PWSCG). The PWSCG commissions weather services on behalf of government and the UK public.

Although the Met Office has no statutory responsibility it is identified as the preferred supplier of meteorological information and services under the Civil Contingencies Act.

The Met Office

September 2011

Supplementary written evidence submitted by the Met Office (MO 00a)

Met Office Funding

Met Office Funding Structure

1. The Met Office is a Trading Fund within the department for Business Innovation and Skills. This means the Met Office:
   a. Has no vote funding;
   b. Must cover costs from revenue earned from customers, both government and commercial;
   c. Has a multi-year Return on Capital Employed (ROCE) target from HM Treasury;
   d. Returns profits to owner as dividends.

2. Under the Trading Fund Model the Met Office returns approximately £10m per annum in dividend. The Met Office commercial business turns over ~£32m and is profitable and absorbs a share of fixed infrastructure costs which could not be significantly reduced in the absence of commercial business.

Met Office Revenue

3. As the Met Office has no vote funding all of its revenues are secured and managed contractually. These contracts vary in type and length but fall into three broad categories:
   a. Government Customer Service Agreements (CSAs).These are multi-year agreements in place to cover primary Met Office services:
      - Public Weather Service (PWS), funded by BIS, the Civil Aviation Authority (CAA) and the Maritime and Coastguard Agency (MCA);
      - Defence Service, funded by MOD;
      - Hadley Centre Climate Programme (HCCP) funded by DECC and Defra.

   b. Other Government contracts – numerous contracts to provide specific weather related services and products to government departments, can be competed with other private weather service providers.

   c. Commercial contracts – a diverse range of value added products and services delivered across a number of market sectors with open competition. Services are priced on a value basis.

   Figure 1 provides a breakdown of the revenues across the categories

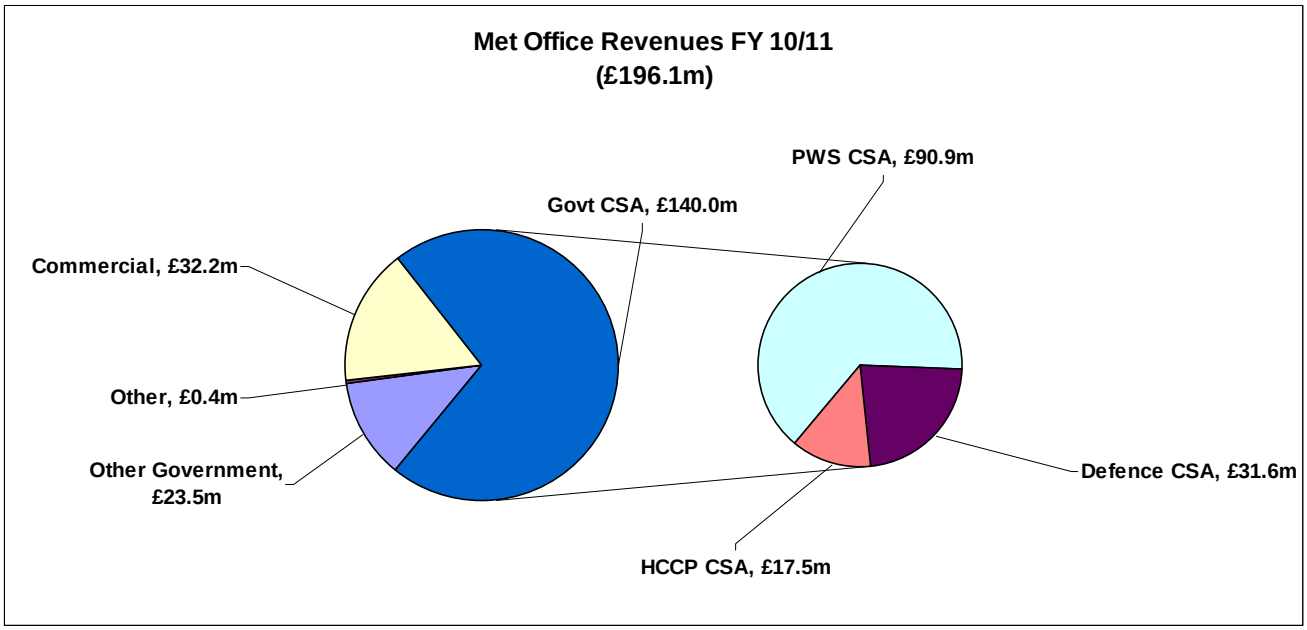


Figure 1: Met Office Revenues 2010/11

Met Office Costs

4. The Met Office has a largely static fixed cost base focussed on a few key categories:
   a. Staff Costs – many of the skills required by the Met Office are unique, particularly weather and climate science, weather forecasting and observing. This results in a large number of staff being trained and developed within the Met Office who then remain with the organisation for the whole of their careers. These unique skills and knowledge are not readily available in the UK job market and are difficult to replace.

   b. International obligations – the Met Office is the UK representative on a number of international treaties (primarily, EUMETSAT, WMO and ECMWF) and has commitments to satellite programmes of 20+ years. This secures UK access to global observational data and knowledge necessary for it to provide the Government CSA services.

   c. Infrastructure – primarily property, observing infrastructure and IT infrastructure and particularly supercomputing. There are large long-term contracts in place to provide this infrastructure.

   These costs are summarised in Figure 2.

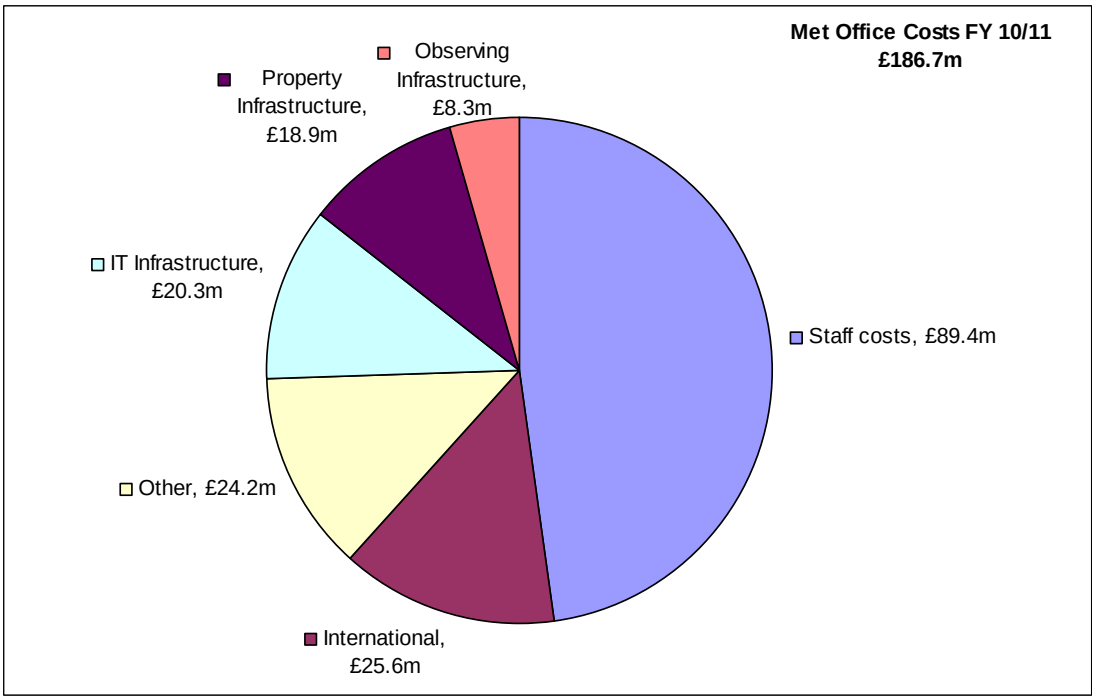


Figure 2: Met Office cost base 2010/11

Issues

5. The Met Office and the customer departments have secured the Government CSA revenues as far as possible by putting in place multi-year Customer Supplier Agreements which describe the outputs which will be delivered and allow for efficiencies to the benefit of both the customer and the Met Office. The key benefit this provides the Met Office is greater security on its revenues to match the long-term commitment of its resources, infrastructure and cost base. The CSAs are priced in accordance with HMT Fees & Charges guidance (cost plus a 3.5% ROCE mark-up).

6. The CSAs are Intra government agreements and are not legally enforceable. Departments can withdraw the requirement for services and the associated revenue. A recent example of this was on the Defence Research programme which withdrew £4.5m of funding for the HCCP with only 3 months notice.

7. Following the withdrawal of MOD funding for the HCCP, Sir John Beddington led a review of UK Climate science needs in 2010, which looked at requirements, funding and governance. The report states "*A key conclusion, and indeed the prompt for the review, is that the existing arrangements have not provided the stability required, and seem unlikely to do so in the future. There are strong arguments for placing resourcing and governance for what is a key national capability on a more sustainable footing, including to facilitate strategic planning and investments. The risk of a continued situation in which the Centre*[1] *lurches from one funding crisis to the next as individual departments,*

[1] The Met Office Hadley Centre

with distributed responsibility, seek to make savings that may not recognise wider Government interests". Following the Beddington review, DECC and Defra agreed joint management of the HCCP, on behalf of Government.

8. Despite the intention that CSAs should be multi-year agreements, currently only the PWS CSA is agreed beyond FY 11/12 and the security of long term funding for all services other than the PWS remains an ongoing issue.

Met Office

October 2011

Written evidence submitted by Anthony John Power (MO 01)

Summary

Your question 1 asks: How effectively is the Met Office fulfilling its Public Weather Service remit?

The Met Office outlines its core task as providing "a range of information" under its Public Weather Service remit which is to:
"produce weather forecasts which help the UK public make informed decisions about day-to-day activities"

RESPONSE

The Met Office is ineffective in fulfilling its Public Weather remit.

It does not, in any meaningful way, produce weather forecasts "which help the UK public make informed decisions about day-to-day activities".

Information.

1. The Met Office would appear to collect a number of statistics relating to the weather - rainfall, wind speed and direction, air pressure, cloud levels, and so on, relating to the immediate past, and add them to stored records from the earlier past. These data are then compared, and an attempt to forecast what will happen, from what has happened in the past, is made. This is then generally transmitted to many forecasters, for their interpretation and input, prior to being broadcast to the public, and results in many different forecasts, even for the same region, being broadcast, none of which is authoritative or even reliable, resulting in considerable confusion.

2. For example, the BBC website will, in its weather 'page' originating from the Met Office, give
    a. a country wide forecast for the next few days in a recording of a live broadcast,
    b. predictions for any local area of choice which is written with a summary for each day for five days.
    c. a 3hr prediction for the same local area graphically as a map, showing one prediction for the end of each three hour period, for the next few days

    which, on most occasions, do not agree with each other. Obviously, they cannot therefore be accurately forecasting what will actually happen.

3. Very many areas of Great Britain do have local climate anomalies, which are usually known locally, but of which no account is taken in the forecast. Furthermore the 'local' area, of some 400 sq miles, is far too large, in some cases, for meaningful forecasting. Moreover, by breaking graphics into 'snapshots' at 3 hourly intervals, there is insufficient continuity to see

what the intervening 3 hours weather is forecast to be. This is a wholly unsatisfactory result, not only for the public but also for the BBC and the Met Office.

4. Most Television channels also have their own interpretation, as do all daily newspapers, and these add a further level of confusion.
5. These anomalies and confusions arise because the forecast issued by the Met Office is unreliable and open to further interpretation, presumably in a hope that the 'local' forecaster, trained or not, will do better than the professionals.

6. When there is a local event, Wimbledon, say, or an Air Show, Race, or other large outdoor event, the Met Office 'local' forecast is usually reliable and accurate.

Conclusion. The Met Office should issue forecast for smaller local areas to achieve greater accuracy.
These should be in the style of a rolling map, much as, say, the BBC do for their daily forecast, but with continuous display of weather expected over a 'local' area, with seamless expansions into larger, up to region, or even national, maps. This way they make a clear forecast for all, their accuracy can be tested, and their consistency will ensure the many interpretations will be unnecessary. Even wind arrows and speeds would give a better indication of changes within the 3 hour periods.

Anthony John Power

September 2011

Written evidence submitted by Malcolm Shykles (MO 02)

This submission relates to Point 4

4. How robust are the models used by the Met Office for weather forecasting, climate predictions, atmospheric dispersion and other activities?

These are the points I am making:-

1. I am not very impressed with the science contained in the articles written by the guest writers on Climate Change on the Met Office web site nor on the Met Office predicted Climate Model at http://www.metoffice.gov.uk/climate-change/guide

The historical view of the Carbon Dioxide Greenhouse Effect is at:

http://www.aip.org/history/climate/co2.htm#S2

This science fails because we now know that CO2 levels were higher in the past than of today. Even Iain Stewart's graph on the Met Office web site shows that over the long term CO2 in the atmosphere is falling. Also Habibullo I. Abdussamatov states that "the increase in greenhouse gases concentration is not the reason of global warming, but on the contrary, the result of the rise of temperature caused by prolonged increase in the TSI. (Total solar irradiance)

2. The current Met Office Climate Model of a "Predicted Climate Change temperature rise to 2100" is for a positive temperature rise which is completely opposite to the view of Habibullo I. Abdussamatov who predicted the cooling trend that the Earth has now encountered.

http://www.gao.spb.ru/english/astrometr/index1_eng.html

3. The heat balance for the Earth can only be measured from sensors from outside the Earth/Moon system and not from within it. No matter what the scientific consensus of opinion is, only that from Universities and bodies such as NASA with access to the necessary satellite data can be considered to be of value.
4. To be considered is the work of Professor Henrik Svensmark director of the Center for Sun-Climate Research at DTU Space. His work is now receiving attention at CERN where their current "CLOUD project aims to study the influence of galactic cosmic rays on the Earth's climate through the media of aerosols and clouds." Their recent paper "Role of sulphuric acid, ammonia and galactic cosmic rays in atmospheric aerosol nucleation" (Kirkby et al., Nature, 25 August 2011) leads to a major leap forward in the understanding and possible control of cloud formation.
5. Nir Joseph Shaviv, of the Racah Institute of Physics at the Hebrew University of Jerusalem, has written a very lucid article entitled "Cosmic Rays and Climate" which fully describes the theory.

http://www.sciencebits.com/CosmicRaysClimate

6. The Met Office needs to break away from current theories as illustrated on its web site and factor in new ideas.

About me;

Malcolm Shykles
Previous Employment:

- Senior Science Technician at Highams Park School
- Pilot Plant Manager at Johnson Matthey - Universal Oil Products
- Analytical Chemist at Shell Chemical Company
- Peer Reviewed Publication

http://www.osti.gov/energycitations/product.biblio.jsp?osti_id=6679016

Declaration of interests; Nothing to declare

Malcolm Shykles

September 2011

Written evidence submitted by Professor John Pyle (MO 03)

Declaration of interest: I am the 1920 Professor of Physical Chemistry at the University of Cambridge and a Co-Director of NERC's National Centre for Atmospheric Science (NCAS). I chair the Met Office Hadley Centre Scientific Review Group and am a member of the Met Office Scientific Advisory Committee. I was a member the committee chaired by Sir John Lawton which recently reported on the Hadley Centre.

I have a long-standing, successful collaboration with scientists at the Met Office to develop and exploit atmospheric chemistry schemes within the Met Office climate model. The nature of research is such that I am also in competition with scientists from the Met office.

The views I express are my own. I will confine my comments mainly to the area of climate research.

Overview.

1. The Met Office Hadley Centre (MOHC) is a world-leading climate research centre – one of very few – with a justifiably outstanding reputation. Its research has been prominent in the various reports of the Intergovernmental Panel on Climate Change (IPCC); scientists from the MOHC have played leading roles in all the IPCC reports. The MOHC Scientific Review Group, which I now chair, has consistently been impressed by the wide range of world class climate science being performed and considers it 'fit for purpose' to support UK Government policy needs in the climate agenda. The MOHC is excellently placed to continue to develop its world class climate capability.

Is the Science strategy robust and achievable?

2. The scientific foci in the science strategy address important and developing themes in the global weather/climate research agenda. There is a clear policy/societal need to understand climate change and variability at small spatial scales and on times scales from years, through decades to centuries. Delivering this understanding is a central part of the strategy. The emphasis in the strategy on Earth system processes is also a necessary advance on previous work; understanding how the climate system could change involves more than an understanding of meteorology and physical oceanography. Chemical, biological and cryosphere process are also key.
3. The MOHC rightly recognise that collaboration, e.g. in Earth system modelling, is essential. They are unlikely ever to have in-house, world class expertise in all these science areas so that developing appropriate collaborations is crucial (see 8).
4. A key part of the strategy is the restructuring of Met Office R&D. There seem to have been various attempts at reorganisation in recent years. This looks to be a good model but only time will tell. I particularly welcome the establishment of a Foundation Science directorate. This looks to be an excellent development and one that could ease some of the tensions in developing a single Unified Model, which is used for both weather forecasting and climate research.

5. The strategy draws attention to the need for substantially increased computing power. The MOHC Scientific Review Group has expressed concern that the Met Office have slipped down the league table in terms of its computing resource; the funding to maintain a higher rank has not been obtained. It is impossible to deliver world class weather and climate science without access to adequate computing capacity. The levels of funding for high performance computing will be a concern in the future.

Senior scientists

6. I have found a very positive attitude from senior scientists at the Met Office to the development of an optimal relationship with academic scientists (see 8-9). They have also been extremely responsive to comments, suggestions and any criticism from the MOHC Scientific Review Group.

The models

7. The Met Office modelling strategy revolves around the use of the Unified Model, in principle a flexible modelling system that can be used to do modelling from very short spatial scales – local weather – through regional weather forecasting to global climate predictions. In all these areas the Met Office model is very highly regarded and in many is world leading.

Collaboration

8. The Met Office and NERC, representing mainly the academic community, have recently entered into a collaboration agreement via the Joint Weather and Climate Research Programme (JWCRP). This aims to build joint research activity in a number of areas, including climate. Earth System modelling is an area where the Met Office needs these collaborations in order to maximise its scientific impact. The intentions of JWCRP are excellent but it would be foolish to underestimate some of the practical difficulties, for both parties. Collaboration will likely entail some loss of sovereignty; effective management of joint programmes will be a challenge. While collaboration between individuals is a longstanding feature, this more institutional collaboration is to be welcomed and encouraged.

9. Among the practical issues being addressed through the JWCRP, there are a number which relate to modelling. The MONSooN project allows Met Office and NERC scientists to work on the same computer codes by sharing a machine hosted in Exeter. This is a major advance allowing much more effective collaborations. Previously (partly due to security issues) work had to be carried out on different computers, using, inevitably, slightly different codes. This made, for example, joint model development a very slow, frustrating and cumbersome affair. I welcome MONSooN enthusiastically; I would like to see it expanded.

10. The Unified Model architecture is often difficult to negotiate and many UK academic meteorologists employ other, easier-to-use numerical models for specific research projects (e.g. mesoscale modelling). The Met Office needs to consider this seriously. I believe the intellectual exchange with the academic community will be increasingly important for the Met Office; if instead, UK academics use other, rival models, this will certainly be to the detriment of the Met Office, and UK science, in the medium and longer term. More thought needs to be given to making their models ‘user friendly’.

Other

11. World-wide there is a momentum towards 'climate services'. Definitions vary but this would include the provision of a wide range of climate information to a number of different customers. There are still many major challenges in climate science, which the Met Office strategy properly recognises. I am concerned that a premature commercialisation of climate science could distract the Met Office from its core activity, as detailed in the strategy. There is, of course, increasing pressure on the Met Office to attract non-government funding. There needs to be continued scrutiny to ensure that the balance is correct and does not detract from delivery of the Met Office's public service function.

Professor John Pyle
September 2011

Written evidence submitted by the European Centre for Medium-Range Weather Forecasts (MO 04)

European Centre for Medium-Range Weather Forecasts

1. The European Centre for Medium-Range Weather Forecasts (ECMWF) is an international intergovernmental organisation supported by 34 States, including the UK, based in Reading UK where it employs about 240 staff and houses a state-of-the art supercomputer and data storage facility.

2. ECMWF was established in 1975 in recognition of the need to pool the scientific and technical resources of Europe's meteorological services and institutions for the production of medium-range weather forecasts and of the associated economic and societal benefits. Medium-range refers to time periods of 3 to 10 days ahead; however, increasingly, extended forecasts are being produced for monthly to seasonal time-scales.

3. ECMWF's annual budget of about £40 million is funded almost entirely from annual contributions from the Member and Co-operating States according to a scale based on their gross national income. The UK contributes around 16% of the ECMWF budget.

4. ECMWF is the acknowledged world-leader in global medium-range numerical weather prediction, the advanced computer observation-analysis modelling technique used to predict the weather. It has a wide-ranging programme of research and development as well as an operational capability that produces weather forecasts every day that are sent to Member State national meteorological services (in the UK, the Met Office) for their use.

5. ECMWF provides specialist training for scientists, forecasters and technicians including those from the Met Office. It also provides employment opportunities including for UK meteorologists, computer technicians and administrative staff.

6. The Director-General of ECMWF is Professor Alan Thorpe who took up his role on 1 July 2011 after previously being Chief Executive of the UK's Natural Environment Research Council and the Chairman of the Executive Group of Research Councils UK.

ECMWF Submission to the Inquiry

How effectively is the Met Office fulfilling its Public Weather Service remit?

7. ECMWF provides the Met Office with medium-range weather forecasts from which its forecasters can produce forecast products for their customers including the public. As ECMWF is the recognised world-leader in medium-range prediction, this assists the Met Office in delivering the best possible forecasting information to its users. All global weather prediction models are routinely evaluated by the World Meteorological Organisation using independent and

Is the Met Office's Science Strategy 2010-15 robust and achievable and how will the strategy help to deliver a better service?

8. The Met Office has a justified worldwide reputation for the scientific quality of its research and development in meteorology, climate change and weather forecasting. It has many well-respected scientists who publish their research in the international peer-reviewed literature. The new Science Strategy reflects well the key areas of development needed to maintain the Met Office's position within Europe and worldwide as a leading national meteorological service.

9. There is a fundamental need for national and international partnerships to achieve the scientific advances required to improve weather forecasts; no national meteorological service can deliver what is needed on their own. The Met Office Science Strategy recognises this need.

10. Met Office scientists collaborate extensively both nationally with the NERC-funded academic research community and internationally both in Europe (such as with ECMWF) and worldwide. This is an extremely effective way in which the required science can be drawn into the Met Office to improve their models and services. An example is the four-dimensional variational data assimilation method developed at ECMWF, which has since been used by the Met Office.

11. In particular, the Met Office and ECMWF collaborate very effectively together on the science of weather prediction with many joint projects, exchange of staff and participation in training and workshops.

What are the roles of the Met Office's Chief Scientific Adviser and its other senior scientists? How do they provide comprehensive and up-to-date scientific advice?

12. One role of the Met Office Chief Scientific Adviser, Professor Julia Slingo, is as a current member of the ECMWF Science Advisory Committee (SAC). Other senior scientists from the Met Office have also in the past been members of the SAC as well as other ECMWF advisory bodies. The SAC brings together Europe's leading scientists to discuss the science of weather prediction and to advise ECMWF on its draft programme of scientific activities including new lines of enquiry to take and on research developments.

How robust are the models used by the Met Office for weather forecasting, climate predictions, atmospheric dispersion and other activities?

13. There are extensive objective international comparisons carried out continuously regarding the skill of global numerical weather prediction models from the Met Office and the other major international forecast centres, including ECMWF. The ECMWF and the Met Office models are in the world-leading category. Over the last thirty years the skill of such weather forecast models has improved very significantly, including over recent years.

14. Regarding climate change, the Hadley Centre is acknowledged as the world leader on climate change modelling, projections and attribution. ECMWF is involved in climate monitoring using re-analysis techniques but otherwise it is not involved in climate change activities.

15. The Met Office has its own regional modelling capability that is used for forecasting fine-scale detail of UK weather over the period up to two days ahead. This capability is recognised internationally as being at the cutting-edge of short-range weather prediction. (Note: this is outside of the scope of the European coordination on global medium-range forecasts associated with ECMWF.)

How effectively does the Met Office coordinate its activities with government departments, non-departmental public bodies, the UK research base and its international counterparts?

16. The UK, via the Met Office, is a Member State of ECMWF, which is a key component of what is known as the "European Meteorological Infrastructure". This infrastructure coordinates meteorological activities in Europe for the benefit of the national meteorological services by increasing effectiveness and efficiency. The Met Office is a member of all the ECMWF advisory committees and of its Council.

17. The Met Office has helped ECMWF and EUMETSAT (that provides the coordinated European weather satellite network) to become European success stories. This in turn has helped the Met Office to excel at what it does.

18. The existence of ECMWF and its operational medium-range weather forecasts, which are provided to the national meteorological services of its Member States, means that these services can focus on activities related to tailored products and services for their customers. This contributes to the effectiveness and efficiency of national meteorological services within Europe, including of the Met Office.

European Centre for Medium-Range Weather Forecasts
September 2011

Written evidence submitted by Prospect (MO 05)

Introduction

1. Prospect is an independent trade union representing 120,000 professional, managerial, technical and scientific staff across the public and private sectors. We have 35,000 members in the Civil Service, related bodies and the wider public sector including over one thousand staff in the Met Office. As well as operational weather forecasting and observing, our members in the Met Office undertake roles in research into all aspects of atmospheric science including climate change and in running and maintaining the huge range of IT infrastructure required for work in atmospheric science. We welcome the opportunity to contribute to the Select Committee's inquiry.

Q. How effectively is the Met Office fulfilling its Public Weather Service remit?

2. A significant number of Met Office staff, particularly in research and operational forecasting areas, have grown up with a strong personal interest in meteorology. This results in a group who are intensely dedicated to their work. Operational forecasting staff are very well aware of the effects the weather can have on people's day-to-day activities. They have a good understanding of their customers' requirements. Specifically in relation to their public work and work with other public service organisations, in recent years the Met Office has greatly improved its links with the emergency responder community through the Public Weather Service Adviser Team. This has helped to deepen Met Office understanding of how improved forecasts and warnings can help to mitigate some of the impacts from severe weather. For example, the knowledge that snow doesn't just disrupt transport but can stop important social services from reaching vulnerable people is a significant motivating factor in ensuring that the detail of forecasts is as accurate as possible. Similarly, the knowledge that severe winds can cause widespread power cuts, structural damage and possibly fatal injuries focuses forecasters on pinpointing the main areas of risk.

3. Prospect members are well aware that their work is under constant and intense scrutiny from the public, and they recognise that this is an inevitable and proper consequence of working for a public body. Nonetheless, delivering services whilst constantly in the public eye is challenging, both on a day-to-day basis and through specific media events. Effectively members are permanently 'on show' but, despite overwhelmingly accurate forecasts, it is often only negative feedback which comes back through the media.

4. The Met Office continuously seeks both to improve the quality of its products and the effectiveness of its severe weather warnings. It has clear Customer-Supplier Agreements in place to define these services each year and a set of Business Performance Measures that provide stretching targets to be achieved. It has recently invested significantly in enhancing the presentation of site-specific information on its public website and further enhancements are due shortly. It is also seeking to enhance the presentation of probabilistic weather forecast information in order to maximise the public benefits of its ensemble forecasting system.

Q. Is the Met Office's Science Strategy 2010-15 robust and achievable and how will the strategy help to deliver a better service?

5. The Met Office has had a Unified Model (UM) for over 20 years, capable of being used for both Numerical Weather Prediction (NWP) and climate studies. The present Science Strategy 2010-15 places this capability at its core and is aimed at extracting the maximum value from the capability. The reorganisation of science into three strands of 'climate', 'weather' and 'foundation' is a key element of the strategy and recognises that there are a range of activities including observational studies of atmospheric processes, their representation in parametrized form in the UM and the development of the underlying UM code that underpin both climate and NWP applications. Whilst there are many challenges to be overcome in establishing a truly seamless forecasting capability, the Met Office is well-placed to tackle these. This level of challenge is welcomed by the staff involved, many of whom are world-leading within their specialist disciplines.

6. One immediate benefit of this for the staff in Foundation Science (FS) has been in writing research plans. The new organisation enables research plans to be written that explicitly promote synergy between Public Weather Service and climate applications whereas previously the work was more segmented.

7. The strategy document itself presents a well-argued case for these organisational and other changes. The clear benefit for the staff involved is that they can easily see how their own personal contributions fit into the overall picture. The attraction of a scientific career in the Met Office is that it provides

opportunities for involvement in genuinely leading-edge research in a variety of fields. These extend from the development of advanced measurement hardware to the use of advanced mathematical techniques to optimise the operational use of meteorological observations. There are opportunities for scientists from a range of disciplines to work together and gain the satisfaction that their research can contribute to the development of improved services that bring real societal benefits. Working in an environment where there is an explicit mechanism in place to bring the benefits of research through to the provision of improved services and warnings remains for many staff one of the major attractions of a career in the Met Office.

8. The use of the Unified Model for both climate and operational Numerical Weather Prediction provides a robust mechanism for identifying systematic errors and developing corrections for these. The ability of research staff to work closely together across these areas and also alongside operational staff increases the effectiveness of the organisation in pulling through new science into the operational work and the provision of services.

Q. What are the roles of the Met Office's Chief Scientific Adviser and its other senior scientists?

9. Staff recruitment and development feature strongly in the science strategy, and it remains one of the attractions of working for the Met Office that it can still provide for full career development. The adoption of three generic roles of Foundation Scientist, Scientist and Senior Scientist provide a structure that is broadly analogous to academic roles of PhD students, junior and senior post-doctoral scientists. The availability of a new Expert Scientist role in the new role-based pay system has also been well received as it recognises the desire of some Met Office scientists to achieve career progression without having to take on management responsibilities.

10. Progression through roles is governed by a scientific skills framework, generally recognised by staff to be a fair and relevant method of both assessing and guiding staff development. Moderation of the assessments made by individual managers through six-monthly group consultation meetings appears to work quite effectively both to ensure a standardised approach and that high performance or development progress are fairly recognised. Failures of the new role system have occurred where it created an expectation that role progression would be nearly automatic following the achievement of required skill levels. Budgetary restrictions are a factor in this regard and in lack of adequate financial recognition for the Expert Scientist career path.

Q. How effectively does the Met Office co-ordinate its activities with government departments, non-departmental public bodies, the UK research base and its international counterparts?

11. Met Office collaboration in research and development activities is longstanding, but given greater prominence in the science strategy. Meteorology has a proud history of international collaboration and Met Office staff have always played a leading role. The new science strategy does, however, place increased emphasis on bringing through the results of such collaboration to improved advice and services. The majority of staff regard this as beneficial overall since it opens up further opportunities to work with top scientists, both nationally and internationally. It also provides some sense of security to staff since it emphasises the need for the Met Office to continue to be the leading player in collaborative activities. Hence, the Met Office needs to maintain capability in all the research fields involved. However, this also entails some risks to the Met Office and it is imperative that it can continue to recruit high quality staff in order to fulfil its strategic objectives.

12. The Met Office's Hadley Centre for Climate Change Research is an excellent example of world class scientists collaborating with institutes across the globe to provide governments and the wider community with reliable, robust scientific advice to feed into policy making. Given the widely held view that climate change will have major impacts on the world and its economies, it is vital that UK Government funding for the centre and its crucial work is maintained.

13. Met Office collaboration with other organisations in the area of operational meteorology is also worthy of note. The Flood Forecasting Centre, set up jointly by the Met Office and the Environment Agency is a good recent example and significant work is being done with other meteorological services and the aviation industry to improve the understanding of the spread and effect of volcanic ash.

Prospect

September 2011

Written evidence submitted by
Professor Sir Brian Hoskins CBE, FRS (MO 06)

Background

Professor Sir Brian Hoskins CBE, FRS
Director of the Grantham Institute for Climate Change, Imperial College, London
Professor of Meteorology, University of Reading

I have performed meteorological research over a period of more than 40 years and have had extensive national and international research and research organisation experience.
I am a Fellow/Member of the National Science Academies of the UK, USA and China.
I am also on the UK Climate Change Committee.

Declaration of interests

I have been on Met Office science review/advisory committees for more than 25 years. I am now a Non-Executive Director of the Met Office and have chaired its Science Advisory Committee (MOSAC) since its inception 15 years ago.

Evidence

1. Despite my significant and increasing involvement with the Met Office over a 30-year period, I continue to maintain my independence from it. Based on my general experience, as well as my knowledge of Met Office science and its application, I would be happy to answer any questions if asked by the Committee. Here, rather than direct my comments to the specific matters raised in the ToR, I will make a few quite general comments which I hope will be helpful to the Committee in its deliberations and indicate which of the matters they are relevant to.

2. The Met Office would be in the top 2 or 3 in the world of almost anyone's lists for weather forecasting and for climate change projection. An important enabling component for this achievement has been its performance of a body of high quality research in both areas and, more recently, its collaboration with others, particularly the academic community in the UK. *(Relevant to #1, 2, 4, 5)*

3. To provide the weather and climate services required by the Public and the Government, and to achieve the financial targets set for the Met Office, it is essential that it maintain its programme of high quality scientific research and collaboration. The 2010-15 Science Strategy of the Met Office aims to ensure this. *(Relevant to #1, 2, 4, 5)*

4. For a number of years some of us have been promoting the benefits of considering the Seamless Weather-Climate problem: prediction on time-scales from hours up to a century and space-scales from kilometres to global. The Met Office is uniquely well-placed in the world to realise this approach because it has both weather and climate in its remit and because it has developed an overall modelling system that it can apply to all time scales. I welcome the fact that this aspect has a central role in its Science Strategy. *(Relevant to #1, 2, 4)*

5. Given the public, user and financial pressures on the Met Office, it is important that in both its long-term strategy and shorter term response to demands, the Met Office does not indicate or promise an actual or potential predictive capability that is beyond what is

suggested by current scientific understanding. An important aspect of this is the need to articulate the uncertainty that is inherent in predictions made on all time-scales, and to encourage its "customers" to accept this and to fully exploit the available information. *(Relevant to #1, 2, 4, 5)*

6. In recent years there has been a great improvement in the Met Office's R&D collaboration, both nationally and internationally. In the UK a unique Met Service-Academia/NERC partnership is developing. The international use of the Met Office global weather forecast and regional climate models is also an important new development. The requirement on the Met Office to gain financial reward from its products could be damaging to collaboration, an aspect that needs to be carefully watched and handled. *(Relevant to #2, 5)*

7. The Met office Scientific Committee (MOSAC) was set up 15 years ago when the then Chief Scientist sought independent advice, following the change to Trading Fund status and the demise of the previous research overview process. The reporting of its findings by MOSAC has evolved over the years. The procedure now is that a Report from me as the Chair is agreed by the Committee and is presented by me to the Met Office Board and discussed by it. A written response from the Chief Scientist is sent out to the Committee following this Board meeting. *(Relevant to #1, 2, 4, 5)*

8. Throughout its existence, MOSAC has been notable in a number of ways. Its membership comprises top atmospheric science academics in the UK and the equivalent of chief scientists from a number of Met Services around the world. Its discussions have been very open on both sides, and the discussion by MOSAC has been probing but supportive. Recommendations made by MOSAC appear to have always been considered carefully by the then Chief Scientist and the majority have been acted upon by the Met Office. *(Relevant to #1, 2, 4, 5)*

9. As the atmospheric scientist on the Met Office Board, I act on behalf of it to agree with the Met Office the technique the application of it for setting its annual weather forecast targets. I then advise the Board on the acceptability of the proposed targets. This process has led to significant modification of those targets in some years. *(Relevant to #1)*

Professor Sir Brian Hoskins CBE, FRS
September 2011

Written evidence submitted by the U.S. National Oceanic and Atmospheric Administration National Weather Service (MO 07)

Regarding an inquiry into Science in the Met Office

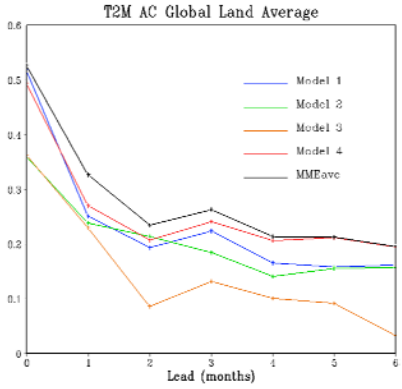
Question 4: How robust are the models used by the Met Office for weather forecasting, climate predictions, atmospheric dispersion and other activities?

4.1 The U.S. National Oceanic and Atmospheric Administration (NOAA) National Weather Service (NWS) feels the models produced by the Met Office are robust. For instance, the NWS National Centers for Environmental Prediction (NCEP) works with the Met Office on land modeling via the World Climate Research Programme (WCRP) Global Energy and Water Cycle Experiment (GEWEX) Global Land/Atmosphere System Study (GLASS). This specifically involves land-model development and land-model "benchmarking" (robust validation). The Met Office's JULES land model is very good, is essentially ***the*** land model in the UK (links weather-water-hydrology-climate at many government labs, institutes, and universities), and bridges numerical weather prediction to climate with carbon, dynamic vegetation, ground water, etc, in addition to the usual surface energy budget closure (bottom boundary condition for atmospheric models).

4.2 After the eruption of Grimsvötn, Iceland, in 2004, an international modeling comparison was conducted among the Volcanic Ash Advisory Centers (VAACs) of London, Washington, Darwin, Montreal and Toulouse, with the result published in a peer-reviewed journal (Witham et al., 2007). It was found that all models showed "strong similarities for forecasting regional ash cloud transport," and that "the model forecasts [were] highly dependent on the amount of eruption information available at the time."

4.3 After the eruption of Eyjafjallajökull in 2010, it was agreed that dispersion modeling strategies, and the application of the dispersion model output for the forecast portion of the required ICAO product, the Volcanic Ash Advisories were not consistent among the respective Volcanic Ash Advisory Centers (VAACs). In particular, the operational HYSPLIT model runs for internal, 'quick look', use were initialized as a new eruption during each run, and in retrospect, underestimated the volcanic ash during sustained eruptions due to non-modeling of 'old' ash. These runs were inadvertently made available to the public and compared to products from the UK VAAC, which were based on different eruption information ('new' and 'old' ash). Subsequently, NOAA NWS had several discussions with the Met Office on the use of the Numerical Atmospheric-dispersion Modeling Environment (NAME), which is used to model a wide range of atmospheric dispersion events. The result has shown again that the NAME is robust, peer reviewed, and good for ash dispersion modeling and has driven an accelerated development of the operational HYSPLIT model to retain volcanic ash from previous runs. NOAA and the Met Office are looking for further collaboration on model development in accordance with broader VAAC collaborative strategy developed at the VAAC coordination meeting in Montreal 2011 and following on meetings at the 2011 American Meteorological Society meeting.

4.4 In July 2010, NOAA became a partner in the European Seasonal-to-Interannual Prediction (EUROSIP) project. The goal of EUROSIP is to strengthen collaboration on enhancing multi-model techniques for seasonal forecasting. Mr. Hirst personally interceded on behalf of the NWS to become a partner, and progress is being made to start receiving real-time forecasts. NOAA's Climate Prediction Center (CPC) is working with EUROSIP and the NOAA Climate Forecast System (CFS) data to develop and test a seasonal multi-model ensemble forecast tool that combines the CFS and EUROSIP later this year. In addition, preliminary tests of the forecast tool at CPC show that the skill of the four EUROSIP models to predict surface temperature over land (as a function of lead in months) is higher than it is for the individual models in the ensemble.



4.5 Reference:

Witham, C.S., M. C. Hort, R. Potts, R. Servranckx, P. Husson and F. Bonnardot, 2007: Comparison of VAAC atmospheric dispersion models using the 1 November 2004 Grimsvötn eruption, *Meteorological Applications* **14**, 27-38.

Question 5. How effectively does the Met Office coordinate its activities with government departments, non-departmental public bodies, the UK research base, and its international counterparts?

5.1 The relationship between the Met Office and NOAA continues to be an extremely positive one at all levels and both organizations have like-minded views on a range of issues.

5.2 In February 2011, a formal Memorandum of Agreement (MoA) was negotiated between the NOAA Space Weather Prediction Center (SWPC) and the Met Office for space weather cooperation. The objectives of the collaboration are to establish 24 hour/7 days-per-week back-up capabilities and to pursue a combined atmosphere-space model to forecast ionospheric disturbances as well as to increase staff interactions, exchange data, and foster operational and scientific collaboration. Space weather is one of the hazards to be included in the Met Office's new All-Hazard Centre, and the back-up capability for SWPC will be part of this Centre. NOAA highly values the interaction with the Met Office on the coordination of space weather services, model development, and exchange of data. In addition, the Met Office has been a strong supporter of space weather within the United Nations World Meteorological Organization

(WMO). Both NOAA and the Met Office view the WMO as an important international forum to enable more countries around the world to benefit from existing services and, subsequently, to encourage other countries to contribute to improved space-weather services.

5.3 In addition, the 2010 eruption of the Eyjafjallajökull volcano in Iceland revealed the limitations in the existing international system for dealing with volcano hazards. During the 2011 American meteorological Society 91st Meeting in Seattle, Washington, the London VAAC, operated by the Met Office, and the North American VAACs (Anchorage, Montreal, and Washington, D.C.) met to (1) lay the ground work for improved VAAC collaboration during future North Atlantic volcanic ash events, and (2) promote scientific exchange concerning observations and modeling of volcanic ash. The overall goal is to ensure a better collaborative effort involving all the major forecast units in North America (USA and Canada) and the Met Office.

5.4 The U.S. has also taken the lead in proposing a Collaborative Decision Making (CDM) approach which includes VAAC collaboration. A working paper was submitted to the ICAO International Volcanic Ash Task Force (IVATF) meeting in July 2011 in Montreal, and the concept of operations for CDM will continue to be refined as it is worked with other principle states. NOAA/NWS Alaska Region is also working with NASA Short-term Prediction Research and Transition (SPoRT) Center and StormCenter Inc. through the GOES-R Proving Ground to develop a volcanic ash collaboration tool using software that allows product display and annotation over Google Earth. A successful test of this tool was completed in May 2011 with a table top eruption of Mt. Redoubt in Alaska. Several Alaska weather offices, University of Alaska Geophysical Institute (AVO), and StormCenter Inc. participated in this test. Many VAACs have expressed an interest in this tool, which may become the basis of a future VAAC collaboration tool.

5.5 The volcanic eruption also provided another area of enhanced collaboration between NOAA and the Met Office. During this period, NOAA provided satellite retrievals of ash cloud height, mass loading, and effective particle radius in near real-time to the Met Office via the web. The NOAA satellite retrievals of ash cloud properties were used to qualitatively assess model performance and were also compared to independent satellite retrievals performed at the Met Office. More detailed comparisons between NOAA and Met Office satellite retrievals are planned.

5.6 NOAA and the Met Office also provide back-up to each other as the only two World Area Forecast Centers (WAFCs), which provide meteorological messages with world-wide coverage for pilot briefings, supervised by the International Civil Aviation Organization (ICAO). In November 2009, NOAA and the Met Office developed a World Area Forecast System (WAFS) Convergence Plan to resolve inconsistencies between NOAA's and the Met Office's gridded products. WAFS is a system for the world wide broadcast of aviation-related weather information via satellite. It is a joint effort of ICAO, the U.S. Federal Aviation Administration (FAA), NOAA, with additional contributions from the WMO, the Met Office, Finland, Canada, and others. The goal of the Convergence Plan is to harmonize turbulence, icing, and cumulonimbus grids produced by NOAA and the Met Office. Progress is going well, and in January 2011, NOAA implemented a three-month test to produce blended products, in

coordination with the Met Office. New blended grids will continue to be labeled experimental until acceptance by the ICAO.

5.7 Other examples of collaboration between NOAA and the Met Office include the following: (1) The Met Office uses NOAA's ocean wave prediction model, Wavewatch III, as their operational wave model. They are actively developing code with NOAA, and (will) have access to the developmental community code. Both NOAA and the Met Office use recent developments and put back contributions into the developmental codes. (2) The Met Office Forecasting Ocean Atmospheric Model (FOAM) is considered regularly in the Global Ocean Data Assimilation Experiment (GODAE) OceanView, although they are not one of the most active partners. In Europe, the Met Office is actively involved in MyOcean. (3) The Met Office is an active and contributing partner to the Group for High-Resolution Sea-Surface Temperature (GHRSST), which provides a new generation of global high-resolution (<10km) SST products to the operational oceanographic, meteorological, climate and general scientific community. The Met Office products are excellent.

5.8 The Met Office Chief Executive also serves as the UK Permanent Representative (PR) with the WMO and is, therefore, the U.S. PR's counterpart, NOAA Assistant Administrator for Weather Services, Dr. John L. Hayes. NOAA and the Met Office continue a positive bilateral relationship within WMO. The Met Office serves as allies on a wide range of WMO topics from technical issues to those dealing with governance. Most recently, NOAA and the Met Office have shared views and mutually supported the WMO direction in a number of areas including the development of Global Framework on Climate Services (GFCS), the focus of the WMO's Disaster Risk Reduction Programme, the evolution of the WMO's Integrated Global Observing System and Information System as well as various management and oversight issues affecting the governance of the WMO.

Declaration of interests: The National Oceanic and Atmospheric Administration has no personal, commercial, or financial interests in the affairs of the UK Met Office.

U.S. National Oceanic and Atmospheric Administration National Weather Service
September 2011

Written evidence submitted by the Australian Bureau of Meteorology (MO 08)

Inquiry into Science in the Met Office

On behalf of the Australian Bureau of Meteorology (the Bureau) I append this agency's submission to the Science and Technology Committee's Inquiry into Science at the Met Office.

As a national meteorological service having similarities in scale and scope to the Met Office the Bureau is well placed to comment against three of the Inquiry's six Terms of Reference. We are pleased to do so for ToRs 2, 4 and 5. As context, background information on the Bureau and its strategy can be found at www.bom.gov.au.

The Bureau has no direct financial interests with the Met Office, but the two agencies participate in numerous collaborative activities that range from individual scientist-to-scientist collaborations and exchange visits by scientific and technical staff, to participation jointly in various international activities under the umbrella of the World Meteorological Organization and other international bodies. The Bureau has, via licence, adopted the Met Office Unified Model (UM) as the atmospheric component of Australia's national earth system simulation capability (known by the acronym ACCESS).

There is therefore quite an intentional alignment between the science strategies of the Bureau and the Met Office, which serves both countries well through the operational focus of the Met Office on the northern hemisphere, and that of the Bureau on the meteorology of the southern hemisphere. Operational use, testing, and development of components of the UM by the Bureau via simulation of weather and climate over Australia and the Southern Ocean feeds back to the Met Office to facilitate model improvements that would otherwise be beyond the focus of the Met Office. In turn, Australia benefits from a state-of-the-art atmospheric component in its earth system simulation capability that has already led to improved forecasts. This is "one plus one equals three" territory, where a strategic alignment of the intellectual capital of British and Australian meteorologists in the use and development of the UM yields added benefit in terms of improved forecasting capability to the citizens of both nations.

Hence the Bureau has had and maintains a strong interest in the science strategy of the Met Office, and in areas of mutual interest the Bureau has formed a well-considered view that the Met Office strategy is robust, is achievable, and is world leading. That is precisely the view that led the Bureau to seek access to the UM and to commit its own resources to assist in UM development where appropriate. Our objective view is that we have partnered with the best.

DR GREG AYERS
DIRECTOR OF METEOROLOGY

Submission

1. **ToR 2: Is the Met Office's Science Strategy 2010-15 robust and achievable and how will the strategy help to deliver a better service?**

2. A prime strategic objective of all national meteorological services is to provide improved accuracy, timeliness and region-specific information to policy makers and emergency managers on weather events that have high societal impact (extreme events). Warning times range from imminent events (nowcasting) through to hours, and ultimately up to century time scales associated with climate change. The Met Office has

adopted a common atmospheric modelling framework for prediction/simulation across all time/space scales. This strategy makes a great deal of sense in light of the best practice envisaged, for example, in 'The World Climate Research Programme Strategic Framework 2005-2015' (WCRP-123 WMO.TD-No.1291). The WCRP argues convincingly that developments in atmospheric science and technology provide the opportunity to address the predictability of the total climate system for the benefit of society via *the seamless prediction* of the climate system from weekly weather to seasonal, decadal and centennial climate variations including anthropogenic climate change. The Met Office is well on the way to achieving that difficult but nonetheless strategic goal of seamless prediction, for the benefit of society.

3. The Met Office Science Strategy for 2010-2015 "takes the new agenda of seamless science and prediction and focuses the Met Office agenda around four major science challenges". This is a fundamentally robust science strategy aimed at achieving societal benefits through improved information and warnings as noted above. In many ways this very focused, intentional approach of identifying and targeting a limited number (just four) of key science challenges is world leading and the Met Office is to be congratulated on its willingness to develop and implement such a strategy to meet future societal requirements. The robustness of the strategy is enhanced through the proposed new Directorate which addresses a key weakness (noted by the Met Office Science Advisory Committee, MOSAC) in the previous structure that did not readily facilitate common developments across the climate and weather research components. The new structure has a "Foundation Science Directorate" sitting between "Climate Science Directorate" and "Weather Science Directorate". This makes very good sense in that it will ensure commonality of science between the two science Directorates. In this vein, not only is the science strategy robust, it is eminently achievable. The Met Office's immediate past record of achievement confirms its ability to deliver on strategy.

4. The past decade has seen major improvements in our ability to provide accurate numerical predictions for weather forecasting over the 1- to 10-day timescales. These improvements are a result of a number of factors including major increases in the observation network and more particularly in satellite data from a wide variety of sensors that provide high resolution (in time and space) information on key atmospheric variables, and development of analysis and assimilation methods that allow effective use of these data. The new strategy rightly and clearly points to the continuing need for the Met Office to maintain significant capability in accessing and assimilating observations from a wide variety of sensors in order to better improve our understanding of atmospheric processes and provide improved initial conditions for forecasts. It is these advances that have underpinned historical forecasting skill improvements which will be built on to ensure that the strategy delivers even better service in the future, including the challenging area of very short-term forecasts.

5. The underlying rationale for this is benchmark science, based on the seamless approach, and as stated in the strategy the approach is fundamentally derived from and grounded in service delivery needs. That is apt. Decision making, whether it is in the domains of emergency management, the agricultural industry, transport, government or for the public benefits from coherent sets of improved information. The strategy of coupling of the outputs from these activities with hazard exposure and vulnerability assessment to provide "all-hazards" risk information through the multi-agency Environmental Monitoring and Risk Centre (EMRC) enables the underlying science to have maximum societal impact. In this sense the focussing of the science represents a fundamental national capability that enables the Met Office to deliver its world leading public good warnings and forecasts, including floods, policy advice and to support emergency management and defence needs.

6. An important means of ensuring that the Met Office science and models remain world class is to have a regular review of the different programmes by an expert group. The Met Office has rightly addressed this by constituting the Met Office Science Advisory Committee (MOSAC) whose members are selected on the basis of their proven track record, and of the relevance of their expertise to the scientific questions underlying the Met Office research programmes. MOSAC meets annually and in the past its remit has included only the weather prediction component. The new strategy, in recognition of furthering seamless prediction and the need for common developments across the climate and weather research components, has widened the remit to include both weather and climate science.

7. In summary it is the Bureau's view that the Met Office's Science Strategy 2010-15 is robust, achievable and will undoubtedly deliver better operational services over the outlook period.

8. ToR4: How robust are the models used by the Met Office for weather forecasting, climate predictions, atmospheric dispersion and other activities?

9. As noted under ToR2, the Met Office is one of the few (and the most advanced) major organisation that uses a common modelling framework for weather forecasting, climate predictions, atmospheric dispersion etc. These models are run at a wide range of horizontal resolutions – 1.5km for weather prediction to ~100km for climate/climate change studies, and wide range of time scales – 36 hours for high resolution weather prediction to several centuries for climate/climate change studies. This places heavy requirements on the unified system, including (i) science requirements – stable numerics, conservation of key variables such as mass, energy, chemical tracers, non-hydrostatic formulation for high resolutions and (ii) technical requirements – model code has to be flexible to run in different configurations and domains (regional and global) and on different computing platforms, and optimised so that the operational weather prediction suite can be run within tight time windows to allow model output to be available to forecasters in a timely fashion while climate/climate change runs spanning centuries need wherever possible to be completed in few weeks rather that in months.

10. These demands are tough. The Met Office has addressed the above issues by forming teams composed of key experts and support staff that are dedicated to addressing the requirements placed on the modelling system and to continuing developments to all components of the system. They have been highly successful in meeting the heavy requirements as evidenced by the near unanimous view held internationally that the Met Office weather prediction and climate prediction models are world class (within the top two in weather forecasting and the world leader in climate prediction and related work). The new strategy and the team structure should ensure that the Met Office is well placed to meet the future developments that will be necessary to maintain this deserved reputation for quality modelling systems. The Bureau is particularly well informed to be able to comment on the point of model robustness, having done a deep "due diligence" on the Met Office and its modelling system before seeking a collaborative arrangement allowing the Bureau to adopt the Unified Model for deployment in Australia. The decision to use Met Office systems in the development of the new Australian national modelling system (ACCESS - see submission of ToR5) was strongly driven by our assessment that the Met Office systems are state-of-the art in modelling, satisfy the seamless prediction approach and are robust in the face of all key requirements for operational weather and climate modelling. The Bureau has no reservations in stating that its decision has been completely vindicated by its first-hand experience operationally with the Unified Model over more than two years. These are excellent models, well-conceived, well built, and well up to the task.

11. ToR5: How effectively does the Met Office coordinate its activities with government departments, non-departmental public bodies, the UK research base and its international counterparts?

12. The complexity of Earth System Models and meteorological and oceanographic data assimilation science has expanded dramatically over the past 20 years. The scope of the advanced science and technology that underpins leading practice in these fields is such that it requires significant resources in research and development and in infrastructure to enable the strategic and tactical application of the science. Given the continuing trend towards increasing complexity it is increasingly difficult for individual organisations to command adequate resources to meet existing and future requirements. As such there is a trend towards entering into national and international collaborative activities. The new Met Office strategy has recognised the importance of such collaboration as shown by the inclusion of "Science Partnerships" in its Directorate.

13. The Australian Bureau of Meteorology has established effective collaborations with the Met Office following a decision by the Bureau and CSIRO (Australia's major national research agency) to use the Met Office Unified Model (UM), data assimilation (VAR) and Chemistry and Aerosols (UKCA) systems in their new and jointly developed Australian Community Climate and Earth System Simulator (ACCESS). The collaborations with the Met Office have been based on the signing of a formal research license between the Met Office, the Bureau and CSIRO that allows use of the software for research and operational use and in return delivers to the Met Office improvements to model components made in Australia. To underpin this process the licence is accompanied by a separate research plan that specifies projects for collaboration between the Bureau/CSIRO and Met Office scientists. The areas of collaboration include model development (numerics and physics), model evaluation, prediction and understanding of tropical cyclones and tropical phenomena such as monsoons and the Madden Julian Oscillation (MJO), regional climate modelling, coupling development/issues, and software development.

14. The success of this collaboration has been achieved through (i) ongoing, structured and fruitful communications between the Met Office external collaboration manager and the Bureau counterpart, and (ii) equally regular and structured communications between ACCESS scientists and their Met Office counterparts, including exchange visits to implement scientific improvements in both directions. Prompt responses from Met Office scientists on problems encountered by the Bureau with initial implementation have ensured rapid advancement of the collaboration. The Met Office has organised annual UM User Group Workshops which have been very useful in fostering collaboration and exchange of information between all users and developers of the UM. The essence of this success is the thoughtful, intentional, and mutually beneficial management arrangements wrapped around the relationship by the Met Office. From the Bureau's perspective, based on several years of experience, the Met Office is very well planned, efficient and effective in the way it structures and manages its side of the relationship with the Bureau.

15. An example of the resultant significant scientific collaboration between the Bureau and the Met Office has been in the area of jointly improving probabilistic approaches to precipitation forecasting, for hydrological applications within the STEPS framework used in both agencies. This approach directly links the heuristic nowcasting approaches with the numerical weather prediction in a probabilistic framework. The key point being made here is not to delve deeply into the technical detail, but to recognise the value produced: that advances in the science are being jointly applied to the benefit of the citizens of both countries. From the Bureau's point of view this makes great sense in terms of effectiveness and efficiency, and we would argue that no less is true for the Met Office. Where our science capabilities are mutually reinforcing we will both progress faster, and better, through collaboration rather than going it alone.

16. Overall the Bureau's experience with this collaboration is highly positive and has provided the Bureau with a major increase in modelling capability that is now being employed for both research and operational purposes. In return we have delivered similarly tangible benefits to the Met Office offering improvements to its operational activities. This is the essence of modern international collaboration in the field of meteorology and earth system science, and it is the case that both the Met Office and the Bureau have adopted this approach multilaterally, not just with each other. That said, we would argue that the Met Office and the Bureau are together demonstrating particularly well the value of mutually leveraging agency capability at the global scale.

17. The Bureau can also observe that the Met Office has developed strong partnerships with the United Kingdom weather and climate science community, particularly the Universities through establishment of the Joint Weather and Climate Research Programme with the National Environment Research Council (NERC) which includes the jointly owned MONSooN high performance computer located at the Met Office for use by university researchers, and conduct of major collaborative modelling experiments such as the NERC-funded CASCADE experiment. Further indication of Met Office involvement with UK Universities is the provision of funding to set up professorial Chairs at relevant University departments and supervision by Met Office scientists of university students. The UKCA consortium is another example.

18. We also note than Met Office scientists are actively engaged with major international initiatives of key agencies such as the World Meteorological Organization's World Climate Research Programme (WCRP), World Weather Research Programme (WWRP), and THe Observing system Research and Predictability EXperiment (THORPEX). This is both appropriate and necessary if the Met Office is to remain a leading player in the development of meteorological and earth system science for the benefit of society..

19. The Met Office's lead role in the multi-agency Environmental Monitoring and Response Centre (EMRC), is an important example of effective engagement with major national stakeholders targeting community impact. The Met Office is a world leader in this area. Key agencies such as the Natural Environment Research Council, the British Geological Survey, the Cabinet Office, the Health Protection Agency and the Environment Agency are involved in translating the weather information into user-required products and services, at regional and local levels. The impact models employed as part of this process are built on the advances achieved in weather and climate prediction.

20. In summary it is the first-hand view of the Bureau as a key collaborator that the Met Office has been effective in coordinating its activities with national and international agencies, and that the new strategy is thoughtfully and convincingly designed to expand these interactions and make them more effective in assisting the Met Office to deliver on its mission.

Australian Bureau of Meteorology
September 2011

Written evidence submitted by the National Oceanography Centre (MO 09)

1.0 About us:

The National Oceanography Centre www.noc.ac.uk was formed on 1 April 2010 by bringing together into a single institution the Natural Environment Research Council's activity at the National Oceanography Centre, Southampton (NOCS) and the Proudman Oceanographic Laboratory (POL) in Liverpool. The NOC works in close partnership with the wider marine science community to create an integrated research capability. Research priorities include the oceans' role in climate change, sea level change and the future of the Arctic Ocean.

2.0 Declaration of interests

The National Oceanography Centre (NOC) and our parent body, the Natural Environment Research Council (NERC), have a long-standing close scientific collaboration with the Met Office including secondment of staff, research contracts, shared ocean and atmospheric modelling activity and joint location of facilities, for example the Met Office ocean scientific moorings team and specialist facility is based at the National Oceanography Centre in Southampton. This team is responsible for a network of marine observing equipment, including nine moored buoys which provide early warning of severe weather conditions, and technical support for drifting buoys and Argo float deployments. The team have collaborated with NOC scientists participating in the Rapid Climate Change and Porcupine Abyssal Plain observatory programmes. In addition, Professor Julia Slingo is a member of the NOC Advisory Council, and NOC director Professor Ed Hill had a reciprocal role at the Met Office Hadley Centre.

3.0 Responses to questions raised by the Committee:

3.1. How effectively is the Met Office fulfilling its Public Weather Service remit?

3.1.1 The Met Office is certainly able to produce short-range weather forecasts of sufficient accuracy for "the UK public to make informed decisions about day-to-day activities". It is able to warn people and organisations about extreme weather with adequate warning to protect life, property and infrastructure. It is only able to do this through continued access to high quality staff, computing infrastructure, and observations from a wide array of platforms and sensors located in space, the atmosphere, the sea surface and below the sea surface (i.e. the 'Argo' network). Many of these platforms are expensive to buy and operate, but the value of the lives and infrastructure that they protect – a single example would be by providing warning of storm surges for London – vastly exceeds the cost of acquiring data. See for example:
http://www.nerc.ac.uk/using/casestudies/documents/storm-surge-report.pdf

3.1.2 Improved fine-scale modelling and understanding of fundamental processes should lead to enhanced accuracy and robustness of regional forecasts. This should benefit the insurance and re-insurance industries who need probabilities of extreme events for their insured losses on timescales of 1 to 2 years ahead. There is a common public perception, however, that the Met Office does not provide reliable *seasonal* forecasts, largely due to sensationalist media reporting and shortcomings in how 'probability' and 'risk' are understood by non-experts. However in contrast to this public perception, significant spending decisions are made based on seasonal forecasts, ranging from a farmer's choice of crop to major construction projects. Private weather forecasting companies are now often called upon to make these seasonal predictions, suggesting that this is an aspect of the Public Weather Service remit where the Met Office service could be improved. The accuracy of forecasts by these private companies needs to be carefully evaluated on a long-term basis. On individual occasions it is quite likely that a private forecaster may outperform the Met Office. Also, the accuracy of the Met Office forecasts should be compared with other national weather agencies. There is also the problem of communicating the forecast. Most of the public perception is via TV broadcasts but the time available for the information to be presented has been shortened. However, more detailed information is available than used to be the case, so the forecasters and weather presenters have difficult choices to make about what to concentrate on.

3.1.3 The Met Office is demonstrating steady improvement in weather and climate predictions through research. For example the improved understanding of the location and duration of slow-moving heavy precipitation events, or intense rainfall from convective rainstorms such as Boscastle, is a result of improved modelling skill, the use of ensemble short-term predictive systems, and investment in supercomputing infrastructure.

3.1.4 Access to historical weather information is good, with straightforward access via the web portal. The Met Office website also provides a large amount of useful information on daily weather with the ability to select specific regions of the UK. Attempts should be made to widen its use among the general public; it contains much more information than the BBC.

3.2. Is the Met Office's Science Strategy 2010-15 robust and achievable and how will the strategy help to deliver a better service?

3.2.1 The Met Office Science Strategy 2010-2015 is a comprehensive, robust and achievable strategy that is welcomed by the science community at the National Oceanography Centre. The proposed four main priorities of Forecasting Hazardous Weather from Hours to Decades; Water Cycle and Quantitative Precipitation Forecasting; Monthly to Decadal Prediction in a Changing Climate; and Sensitivity of the Earth system to Human Activities provide a wide spectrum of research expertise to meet the challenges faced by the UK and the rest of the world through the 21st Century.

3.2.2 The Strategy recognises that the separation between weather and climate research is no longer required and that there is a need for a seamless approach to modelling and prediction. The proposed new structure for delivering Met Office research and development will encourage joined-up working across all weather/climate scales and should foster a closer research partnership with the very capable UK and international research community that is located outside the Met Office, bringing all-round benefit.

3.2.3 The Strategy is underpinned by the emergent Met Office-NERC strategy on Earth System Modelling which is being delivered through the Joint Weather and Climate Research Programme (JWCRP). This is a strategic partnership which is fostering much closer working relationships between NERC and Met Office scientists in building improved models to focus on climate change predictions on timescales of up to centuries. Similar links exist through the NCOF (National Centre for Ocean Forecasting) partnership (also part of JWCRP) which focuses on improved ocean forecasts on timescales upwards of a few days. By strengthening links with the NERC community in these ways, the robustness and achievability of the Met Office strategy is enhanced, as are the resulting services from their forecasting systems.

3.2.4 Access to core scientific expertise will be necessary across organisational boundaries and the Strategy advocates expanding the successful partnership with NERC on the Joint Weather and Climate Research Programme and sees the Met Office playing a key role within the Living With Environmental Change programme. The proposed three Directorates (Climate Science, Foundation Science and Weather Science) lend themselves well to cross-organisational working and collaboration. It is further noted that even though Climate Science and Weather Science are separate Directorates, they are working towards an integrated approach through their adoption of the seamless modelling strategy, in which a traceable hierarchy of related modelling systems will span all relevant time and space scales.

3.2.5 NOC welcomes the proposals to:

- Bring together a more structured approach to partnerships with Unified Model users.
- Strengthen and extend the Joint Weather and Climate Research Programme with NERC.
- Develop a more effective relationship with the Research Councils and the LWEC programme.

3.2.6 We particularly welcome the establishment of a Met Office Academic Partnership Scheme and the establishment of Met Office Industrial Fellowships.

3.2.7 Under section 6 of the Strategy the proposals to encourage retention and development of scientists by allowing more opportunities for advancement, creativity and innovation are very positive.

3.2.8 The ‘Expert Scientist’ and ‘Research Fellow’ roles will provide excellent opportunities for collaboration with the wider research community, though suitable financial arrangements will need to be set up to allow the interaction to take place. University and Research Council scientists are already heavily committed and assigned to costed research programmes so formal partnerships and collaborations with the Met Office will have to be paid for somehow.

3.2.9 The recommendation to provide more opportunities for Continued Professional Development is important.

3.2.10 We agree with the need to develop a much stronger capability in computational science and software development. The multi-core, massively parallel petascale computers require a very large investment in resources to achieve their full potential. NERC centres are well placed to work with the Met Office to help address this resource requirement.

3.2.11 Supercomputing is a fundamental requirement for understanding ocean and atmospheric processes and will require continued funding, collaboration and ‘joined-up’ working to maximise potential.

3.2.12 Observations are critical for advancing and testing the models and theoretical understanding the ocean-earth-cryosphere-atmosphere system. The marine science community relies upon in-situ observations from above, afloat and below the sea surface, and this requires platforms such as satellites, aircraft, ships, buoys and autonomous floats such as the ‘Argo’ profilers. The Strategy recognises these needs.

3.2.13 Space borne Earth Observation is tremendously important to marine scientists to ‘fill-in the gaps’ in observations of the sea surface and increasingly to enable the full range of air-sea surface interactions to be measured. We look forward to working more closely with the Met Office, including through the Global Monitoring for Environmental Security (GMES) programme, to see investment in new instrumentation and platforms, and to ensuring delivery of an operational product through calibration and validation. NERC and the Met Office worked together in successful advocacy for UK participation in the Jason-2 and -3 altimetric satellite missions.

3.2.14 The Met Office has an important role to play in International leadership, including continued support of the IPCC, WWRP and WCRP. The National Oceanography Centre will welcome a strong lead from the Met Office in the relevant international fora.

3.2.15 Communicating science enables policy makers and the public to act upon the knowledge gained by scientists and address the challenges that face the UK and the world in a century that promises to show the impacts of climate change, reduced fresh water availability, growing human population, changes to land use and many other parameters that require active management, stewardship and adaptation. These are highly political issues. Communicating the underpinning science, with its associate uncertainties, to

policymakers and the general public requires particular approaches and skills that have not historically been part of the scientist's toolkit.
The Met Office Strategy recognises that staff will need training to become better communicators and that there must be openness and transparency on research, methods and data.

3.3. What are the roles of the Met Office's Chief Scientific Adviser and its other senior scientists? How do they provide comprehensive and up-to-date scientific advice?

The main roles of the Met Office Chief Scientist and other senior scientists are to take a strategic overview of, and to coordinate and rationalise, the scientific activity of the Met Office. The Chief Scientist has a deep and extensive knowledge of both the Met Office and external UK research capabilities and systems, and is widely acknowledged as an international expert in her scientific fields. Other senior scientists are similarly highly regarded in their fields, and have an extensive knowledge of Met Office capabilities, and a growing appreciation of the skill base in the external UK community (e.g. through interaction with NERC in the JWCRP programme and in the delivery of NERC's strategy through the development of Thematic Action Plans). They are therefore in a strong position to provide robust and sound advice to HMG, UK and international scientific institutions, and the IPCC assessment process.

3.4. How robust are the models used by the Met Office for weather forecasting, climate predictions, atmospheric dispersion and other activities?

Historically, the Met Office have been viewed as somewhat insular. However, the situation is now much improved through the adoption of common modelling systems and approaches, shared with the external (RC, UK Academic, and European) research community. Specifically, NERC and the Met Office now share a common computational platform, MONSooN, which is greatly aiding collaboration with the external community, and pull through of research from the external community to the Met Office. Furthermore, the Met Office and NERC have adopted a common ocean modelling system, NEMO, and have formed a strategic partnership to develop and utilise this model within the JWCRP framework. A common UK configuration of NEMO has been adopted by NERC and the Met Office, implemented on MONSooN, jointly analysed by the two groups, and now forms the backbone ocean model in use in the Met Office systems today. The work programme is overseen by a joint management committee. In addition, both the Met Office and NERC are partners in the international NEMO consortium for the wider development of the NEMO ocean model. Through such increased and effective collaboration with the external community, the robustness of the Met Office ocean modelling systems is now excellent, with NEMO providing a world-leading system.

3.5. How effectively does the Met Office coordinate its activities with government departments, non-departmental public bodies, the UK research base and its international counterparts?

3.5.1 Within the marine research community the Met Office is represented by a senior scientist on the government's Marine Science Co-ordination Committee and participates in work packages such as science alignment and the co-ordination of long-term marine observations. The Met Office contributes to the work of the Environmental Research Funder's Forum, and the Ocean Processes Evidence Group.

3.5.2 The Met Office is represented by a senior scientist as part of the UK delegation to the Intergovernmental Oceanographic Commission of UNESCO, and has contributed substantial technical expertise to component programmes such as GOOS (the Global Ocean Observing System), JCOMM (the Joint IOC/WMO Commission on Oceanography and Marine Meteorology) and tsunami warning systems. The possibility that a tsunami warning system capability might be incorporated into the Joint Flood Forecasting Centre operated by the Met Office and the Environment Agency is being explored.

3.5.3 The Met Office has a close working relationship with the Natural Environment Research Council through the Joint Weather and Climate Research Programme (as already indicated in 3.4 for ocean modelling) and is increasingly playing a key role in the cross-Government, cross-Research Council programme on 'Living with Environmental Change' (LWEC). In addition the Met Office works closely with the UK marine research community in many other areas, including the National Centre for Ocean Forecasting, national capability in deep water moorings, technology development, the training of PhD students and seminar programmes. However we would welcome a more joined-up collaboration with the Met Office in the area of future sea-level rise research.

3.5.4 There is frequent interaction and exchange of staff between the Met Office and the Research Council and University research sectors, with scientists passing between employers and transferring ideas and skills. Under the proposed Met Office science strategy these links will be strengthened, and Met Office scientists afforded the opportunity to enjoy university-style freedom to undertake curiosity-driven research for up to 20% of their time. This will very much strengthen the science base of the Met Office and make it a much more attractive employer to the brightest Post-doctoral researchers. However, it seems doubtful that this opportunity could be afforded to all Met Office scientists.

3.5.5 In general some parts of the Met Office such as the Hadley Centre work much more closely with the outside world than the core part of the Met Office, which partly explains the international recognition accorded to the Hadley Centre. Under the proposed science strategy the alignment of weather and climate research should enable the Met Office to become more outward-focussed and better able to interact with a wider community.

3.5.6 Since its inception in 2000, the UK contribution to the Argo profiling float programme has been managed by the Met Office with strong support from NOC (Southampton and Liverpool). This function has been carried out successfully against a background of perpetual funding uncertainties. The Met Office has also been active in the international coordination of Argo.

3.5.7 The move of the Met Office into BIS, home of the Research Councils, should also facilitate an enhanced interaction with a wider community.

This submission on behalf of the National Oceanography Centre prepared by Stephen Hall with input from : Adrian New, Andrew Willmott, Kevin Horsborough, Jacky Wood and Trevor Guymer

National Oceanography Centre
September 2011

Written evidence submitted by Rowan Douglas (MO 10)

It is with pleasure that I make a submission to the Select Committee on this important subject. However it is with considerable regret that I have not had sufficient opportunity in recent weeks to prepare the detailed written submission that this matter deserves before today's deadline. I would be delighted to speak with the Committee, accompanied by a senior member of our hydro-met research staff, to provide a more comprehensive response to the inquiry's terms of reference and answer any questions you may have.

I enclose a biography with interests at the foot of this submission. With particular reference to the Met Office Willis Re has been a client of the UKMO in recent years, purchasing data and also a founder/development client of the emerging climate forecasting services. Through our academic partnership programme, the Willis Research Network (WRN), we also support a research post at the UK Met Office and a number of posts at the University of Reading and the University of Exeter focussed on research employing Met Office/Hadley Centre climate models.

The role of our industry is to enable populations, at global and local scales, to share the costs of extreme events via public or private mechanisms. As an international insurance and reinsurance broker our interest is the current and near future risk of extreme weather events and understanding their patterns of location, temporal distribution, frequency, severity and impact. Hydro-meteorological perils are the largest single source of risk to the non-life re/insurance industries and have become a key focus of financial regulatory oversight of our sector in the UK, Europe and beyond.

Better access to historical met data and the fusion of this with other information via new forms of tools, known has catastrophe risk models, have provided a significant improvement to the industry's ability to manage natural catastrophe risks over the last twenty years. However, in a non stationary climate, we are reaching the limits of what historical data alone can tell us about current and near future patterns of extreme weather events in the UK and overseas, including extra-tropical storms and north Atlantic hurricane. This has led to two significant areas of research and development in which the UK Met Office has developed an important and early international lead.

The first is in the use of high resolution global climate modelling to develop new information on patterns of hazard and risk at global and regional scales. The second, which is quite revolutionary, but integrates with the wider World Meteorological Organisation framework agenda, is the development of operational climate forecasting services. The opportunity for the re/insurance market to better manage risk and provide protection if it is possible to forecast relative levels of risk in key zones over an 18 month horizon would be an enormous step forward. We are not their yet, but the UK Met Office is widely recognised by leading re/insurers in the UK and overseas as having the most advanced and promising programme in this area at the current time.

In fact a new supply chain is beginning to operate, via the common medium of the *modelled world* from blue-sky climate science, through to applied research, into

industrial applications and regulatory oversight. The UKMO has located itself at the heart of this emerging sector. This emerging supply chain has been described in a recent WMO publication which may be of interest to the committee in the context of this enquiry.

http://www.wmo.int/pages/publications/bulletin_en/60_1_Douglas_en.html

From our own perspective and needs, the UKMO has undertaken a strong commitment to fulfil it public weather service remit to our industry and the populations and institutions serve, within the commercial framework and financial environment under which it operates.

UK re/insurance institutions cover risks within the British Isles and across the world and a particular and specific benefit of the UK Met Office is the capability of serving the interests of the UK industry at a global as well as national scale. It is an institutional asset for the continued position of the UK insurance sector. The UKMO has a unique agenda of unified forecasting not just through a continuum of temporal scales (from days to decades) but also at spatial scales (from local to global), this is strongly aligned with the needs of this sector and many other industries and user communities.

This leads me onto the combined areas of the UKMO Science Strategy and its models. The strategy is certainly robust, clearly articulated and in tune with both user needs and scientific and computational possibilities. In fact, in my experience, the expression of the UKMO science strategy is respected by many other agencies overseas. It is achievable? This is a journey in science as well as industrial innovation and while there can be no certainties it seems extremely likely that significant progress will be made along the pathways identified in the strategy during this period.

Perhaps the best way of conveying our sentiments on the UKMO Science Strategy and its climate models is through our actions. We have the privilege of relationships with other leading climate research centres including the National Center of Atmospheric Research (NCAR) in Boulder Co. and various NOAA related facilities including GFDL at Princeton and Oklahoma, whom we also support. However our commitment to the UKMO and related UK University Centres employing their models has been undertaken for longer, at a larger scale and is continuing to grow. This is based on our assessment of the Office's science, models, commitment to applications and its leadership.

This brings me on to the role of the Chief Science Adviser. It is difficult for me to separate the role from the performance of the current incumbent who is the only UKMO CSA with whom we have dealt. In our view Professor Slingo has provided outstanding scientific leadership and a critical link in understanding the needs of user communities and integrating this within a rigorous and coherent science agenda. She has been assiduous in communicating this to audiences within our sector and beyond and enabled financial and other user communities to understanding how UKMO science and services can become an important component of risk management, resilience and sustainable growth strategies. Her influence has extended across the world in our sector.

From my experience of the JCRP via NERC and of national and international climate and weather research among the members of the WRN and wider communities my sense is that the UKMO coordinates well with its counterparts and this continues to deepen which is a growing necessity for all weather and climate research centres.

The UKMO's new home within BIS may offer and even more conducive context for creating a framework for the UKMO to enjoy even greater freedom to coordinate, collaborate and integrate with partner institutions in public, private and academic sectors at home and overseas. As more parties become increasingly sensitised to the utility of UKMO expertise and its related models and tools this framework and opportunities should be examined and optimised carefully in the months and years ahead.

Rowan Douglas,
CEO Global Analytics Willis Re
& Chairman, Willis Research Network
September 2011

Written evidence submitted by the Royal Meteorological Society (MO 11)

How effectively is the Met Office fulfilling its Public Weather Service remit?

1. The Public Weather Service (PWS) is, in our view, a world class service, providing important warnings for the protection of life and property from hazardous weather events. The value of the PWS is demonstrated many times over each year through the impact it has in helping civil contingencies and raising public awareness in events such as the London Bombings, the Buncefield fire, the 2009 floods, and the wider global impacts for the UK, UK citizens overseas and UK international development initiatives, such as volcanic ash advisory services and the radioactive atmospheric dispersion issues from the Fukushima power plant melt-down.

2. The role of the Public Weather Service Customer Group is key to providing an independent review of the Met Office's effectiveness in fulfilling the PWS remit. The Customer Group ensures that Government is obtaining best value for money, setting and measuring performance against focused targets and ensuring that the public are afforded the protection provided by the latest scientific knowledge and understanding.

3. In our view the PWS Customer Group would benefit from widening its reach, not necessarily in terms of its membership, but in terms of those it consults to ensure that it is meeting the wider public need.

4. Further, it is important that there is a clearly defined boundary between the Public Weather Service provided free-at-the-point-of-use and those paid-for services which are provided through a competitive market place by organisations such as the Met Office and the private sector weather provider community. In our view a review of this boundary would be valuable and timely. This review should consider, amongst other things, the different models adopted in different countries and, with economists and meteorologists working together, consider whether other models that make more public data and information freely available would help to grow the UK's private sector weather provider community and return greater economic value to the UK.

Is the Met Office's Science Strategy 2010-15 robust and achievable and how will the strategy help to deliver a better service?

5. It is important to begin by noting that the Met Office exposes its Science Strategy to regular scrutiny and reviewed by an expert committee of national and international scientists.

6. We are aware that there are others from across our scientific community membership that are providing a detailed contribution to this inquiry on the content of the Met Office's Science Strategy, therefore our comments focus on four more general issues.

7. Firstly, we believe that the Strategy does reflect well the key challenges and priority areas for achieving the greatest return on the investment in the science and the research programme. In our view, the areas of focus are well chosen in terms of delivering maximum value to improvements in both weather and climate services.

8. Secondly, there is no more challenging problem in computational science than that of simulating the Earth's climate, and availability of computing resources continues to be a significant factor in limiting the skill and reliability of weather and climate forecasts. Whilst we recognise the financial challenges the UK faces, we do believe that a further significant investment in computing resources is required, over and about the current commitments. This problem may only be solved by pooling resources with our international partners to provide top tier supercomputing resources dedicated to the climate problem.

9. Thirdly, strong partnerships with the wider science community, both in the UK and internationally, is essential in ensuring that the UK gains the maximum leverage from its investment in the Met Office.

10. Fourthly, across each of these science areas, it is important that the Met Office looks to exploit the value of probabilistic forecasting methodologies. These methodologies allow uncertainties in the forecast, arising from imperfect starting conditions and imperfect models, to be quantified. The reliability of weather-sensitive decision-making will be improved enormously if flow-dependent predictive uncertainties can be properly quantified. The Met Office has taken a lead in the production of probability forecasts for climate, through the latest UK Climate Projections (UKCP09) project and its input into DEFRA's Climate Change Risk Assessment. However, for climate prediction and its application to Climate Change Risk Assessment (CCRA), there remains a fundamental unsolved question of whether the estimated UKCP09 probabilities are actually reliable (for example, does an estimated 90% probability of an event mean the event is somehow very likely to happen?). In the coming years, future CCRAs should ideally explicitly take into account predictions from a range of models worldwide, not just the Met Office's Hadley Centre Model. More generally, and looking further into the future, representing uncertainties in weather and climate modelling is a critical area of cutting-edge research, and new stochastic methods are emerging from the academic and other operational centres (for example the European Centre for Medium Range Weather Forecasting, ECMWF) from which the Met Office should be able to benefit.

11. For day-to-day weather prediction the Met Office has much further to go in providing estimates of forecast uncertainty to the public. If the Met Office was able to provide more information about uncertainty in its forecasts, it may be less subject to the criticism it has seen from time-to-time from public and media alike. Here, working with the BBC (who have editorial control of the broadcast weather forecasts) is crucial, to develop and broadcast graphical techniques for representing uncertainty. There may be some useful parallels from other areas of public information, for example with the Bank of England's methods to represent uncertainty in its forecasts of inflation rate and gross domestic product.

What are the roles of the Met Office's Chief Scientific Adviser and its other senior scientists? How do they provide comprehensive and up-to-date scientific advice?

12. The Met Office is a science-based organisation and the work of the Met Office Chief Scientist, supported by other senior scientists, is in our view essential in order to ensure world class scientific leadership; that is:
    - there is an organisational framework that promotes and fosters innovation and scientific excellence;
    - the programmes of work remain connected to and focused on the key science issues;
    - there is scientific integrity in the work of the organisation;

- the Met Office continues its work in developing effective national and international scientific partnerships; and
- those working in scientific programmes have the necessary competencies, training and professional development.

13. The Met Office Chief Scientist and the senior scientific team remain actively engaged with the wider work of the national and international science community. There are many examples of this, including the Met Office's continued commitment to ensuring that its early career scientists participate with the work of our Society's student conference, the establishment, with the Research Councils, of the UK's Joint Weather and Climate Research Programme, the introduction of the new academic partnership programme and the international collaboration on numerical weather prediction, both with the European Centre for Medium Range Weather Forecasting (ECMWF) and through the Met Office's own partnership with Australia, New Zealand, Norway, and South Africa (to recognise just some of the notable international partners).

How robust are the models used by the Met Office for weather forecasting, climate predictions, atmospheric dispersion and other activities?

14. In our view the Met Office is widely and independently recognised as a world-leader in weather and climate modelling and prediction.

15. The whole suit of Met Office models are exposed to a rigorous testing, validation and verification programme which is open to wider national and international scrutiny. In particular performance against targets, defined both internally and externally, is widely publicised. Further, the models are regularly verified again observations and other models and this process is used to help in continually targeting areas for greater improvement.

16. Having said that, simulations of climate are still far from perfect, and for many variables, the biases of the climate simulations against observations can be as large as the climate change signal which the models try to predict. There are a number of reasons for this, which evolve around the basic notion that climate is an enormously complex multi-scale physical, chemical and biological system - as mentioned above, there is no more computationally complex problem in science. In recent years, climate institutes have begun to develop their climate models to reflect this so-called Earth-System complexity, but the institutes, including the Met Office, are constrained both by limited human resources, and computing resources (as highlighted above). In the light of these constraints, there is an urgent need to review whether the best way forward is continue with largely institutional-based modelling effort (for example the Met Office Hadley Centre model, the Max Planck Institute model, the Meteo-France model, the EC-Earth model etc), or to try to pool human and computing resources, for example within Europe, thus taking advantage of economies of scale. The establishment of the Airbus consortium provides just one an analogy for such a development.

How effectively does the Met Office coordinate its activities with government departments, non-departmental public bodies, the UK research base and its international counterparts?

17. The Met Office has only recently moved its owning department from the Ministry of Defence to the Department for Business, Innovation and Skills. It is difficult to comment on whether this new governance framework is working effectively.

18. Aside from this, the Met Office has a range of mechanisms through which it co-ordinates its activities with its stakeholders, several of which have already been mentioned in this submission. A common theme in these is the openness to external scrutiny and review.

19. In addition the Met Office represents the UK's interests in a range of international groupings such as the European Centre for Medium Range Weather Forecasting (ECMWF), the European Meteorological Satellite Agency (EUMETSAT) and the World Meteorological Organization (WMO). The UK benefits significantly through this sharing of responsibilities, funding and coordinated planning with the Met Office's international counterparts and partners. Without these partnerships in place it would simply not be possible to deliver the range of services provided by the Met Office for the UK.

Declaration of Interest, details and contacts:

20. The Royal Meteorological Society is the UK's Professional and Learned Society for Weather and Climate. The Society is a registered charity, based in Reading, UK, and works to advance the understanding of weather and climate, the science and its applications, for the benefit of all. The Society supports those with an interest in weather and climate in the UK and around the world. Society members include scientists, students, practitioners and amateur enthusiasts and the Met Office is a Corporate Member of the Society.

21. The current President of the Society is Professor Tim Palmer FRS. More details about the Society can be found on our website at 'www.rmets.org'.

Royal Meteorological Society
September 2011

Written evidence submitted by the

Committee on Climate Change (MO 12)

Summary:

- The Met Office is an important provider of advice and data on climate science to the Committee on Climate Change (CCC) through directly commissioned research and indirectly through contributions to the Intergovernmental Panel on Climate Change (IPCC).
- The quality of their work for us has been high, showing balanced judgments from peer-reviewed evidence without underplaying uncertainties or limits to knowledge. Few other institutions around the world have the same breadth of expertise in climate science.
- There is a need for greater availability of weather and climate data in order to assist Government, businesses and individuals to adapt to climate change.

About the CCC:

The Committee on Climate Change (CCC) is an independent statutory body established under the Climate Change Act (2008). We advise the UK governments and devolved administrations on setting and meeting budgets for reducing greenhouse gas emissions, and on preparing for the inevitable impacts of climate change.

Since December 2008 we have recommended the level of the 2050 target for UK emissions and the first four carbon budgets (out to 2027); this advice has been accepted by Government and legislated by Parliament. Through our Adaptation Sub-Committee (ASC) we have also published two reports assessing how well the UK is adapting to the changing climate.

Main text:

1. The CCC has direct experience of working with Met Office scientists, having commissioned research projects and attended several workshops and bilateral meetings involving senior Met Office staff. In addition, both the CCC and ASC have used publicly-available weather and climate data products from the Met Office. Their advice and data has played an important role in underpinning our advice to Government on UK emissions reductions.

2. We are therefore in a position to comment on several issues covered by this enquiry. Our comments follow the relevant questions from the terms of reference:

- *How effectively does the Met Office coordinate its activities with government departments, non-departmental public bodies, the UK research base and its international counterparts?*

3. As a non-departmental public body we have worked closely with the Met Office on two separate reviews of climate science to inform our recommendations on the long-term path of UK emissions. The first, in 2008, involved projecting future global temperature rise for a set of global emissions trajectories throughout the next 200 years. This formed a key part of our advice on the UK's 2050

target to reduce emissions by 80% below 1990 levels, and the outputs are publicly available on our website (see technical appendices to Chapter 1 of our first report[1]).

4. The second research project was commissioned in 2010 as part of our work on the UK's fourth carbon budget, and reviewed the latest evidence on climate risks in order to see if the long-term level of UK ambition remained appropriate. This time the Met Office led a consortium of academics from different research groups around the country. Again, the final report is available on our website (see the AVOID report accompanying our main report on the fourth carbon budget[2]). The AVOID consortium is a useful example of how the Met Office can work with other parts of the UK research base to provide timely advice for decision makers.

5. More informal links are maintained through occasional meetings between Met Office and CCC staff. In addition, one of the CCC members is on the Met Office Board and chairs its scientific advisory committee, and one of the CCC secretariat is allocated some research time at the Met Office as a visiting scientist.

- *What are the roles of the Met Office's Chief Scientific Adviser and its other senior scientists? How do they provide comprehensive and up-to-date scientific advice?*

6. We have engaged primarily with senior scientists through our commissioned work and through shared attendance at meetings, conferences and Government-organised workshops. In their work for us we have found them knowledgeable and professional, with an emphasis on peer-reviewed literature as the most authoritative source of evidence and a willingness to have their conclusions scrutinised by independent experts. We have found their reports give a balanced picture of the scientific knowledge regarding the causes and consequences of climate change, making clear where there is still measurement uncertainty or a lack of knowledge. These methods give us confidence in the quality of their advice.

7. Several Met Office scientists make important contributions to the Assessment Reports of the IPCC, which also benefit from the general research output from the Met Office. As the most authoritative sources of information on climate science, these IPCC reports are an invaluable reference for decision makers around the world, and are used extensively within the CCC.

8. Only a few research institutes in the world have expertise across such a broad range of weather and climate science disciplines as the Met Office. These institutes have a key role to play in aggregating and integrating new knowledge across the different aspects of the science.

- *How effectively is the Met Office fulfilling its remit to provide public access to historic weather information via the Library, Archive and climatological records?*

9. Access to relevant historic weather information is a vital tool in adapting to climate change. One of the most practical ways for an organisation to start preparing for the impacts of climate change is to understand its vulnerability to current climate, especially recent extremes of weather. Despite this, our work on assessing action on adaptation to date suggests that Government, businesses and

[1] http://www.theccc.org.uk/reports/building-a-low-carbon-economy/technical-appendices

[2] http://www.theccc.org.uk/reports/fourth-carbon-budget/supporting-research

individuals may not have access to adequate weather data for this purpose (see Box 3.3 in our first adaptation report[3] and for instance a recent Lloyd's report on East London Extreme Rainfall[4]).

10. By contrast much more weather data is freely accessible in the United States, whose National Weather Service is purely publicly funded. A more vibrant private sector has grown up around this core data, providing tailored products to the paying public. Given the range of different data types that is increasingly required (from simple rainfall measurements through to more complex, secondary products such as depth and duration of surface water flooding in a specific location) a balance needs to be struck between what the Met Office provides through public funding and what is left to commercial interests. Government should actively consider this balance and also work to ensure that data already collected by the Met Office as part of its public remit is made more readily available.

Declaration of interests: none to declare

Committee on Climate Change

September 2011

[3] http://www.theccc.org.uk/reports/adaptation/1st-progress-report-2010

[4] http://www.lloyds.com/~/media/Lloyds/Reports/Emerging Risk Reports/East London Extreme Rainfall_Finalv2.pdf

Written evidence submitted by Research Councils UK (MO 13)

Executive summary

- Research Councils UK (RCUK) regards the Met Office as being very effective in fulfilling its public weather service remit. The Met Office makes good use of RCUK supported models, expertise and capability in providing related services such as hazard warning and data sharing.
- RCUK supports the overarching goal of the Met Office Science Strategy to develop seamless prediction systems across all timescales for the ocean, atmosphere and land surface, as appropriately ambitious with significant advances achievable. The four major science challenges will deliver key science advances, data and services nationally and internationally. The emphasis given to building stronger partnerships is both welcome and essential as continued progress in many areas is reliant on the translation of RCUK funded research. The Met Office has recently restructured around weather, climate and foundation science (the latter underpins and links its weather and climate needs).
- It is important to recognise RCUK supported research and the science supported and utilised by the Met Office have distinct drivers and objectives. The Met Office supports science to improve its operational weather predictions and deliver advice to help customers with their climate related policy and business decisions. RCUK supports world leading fundamental research in weather, climate science and related areas such as hydrology and flooding. Collaborative working results in continual improvement to the world leading service provision of the Met Office and enhanced research capability and impact for RCUK.
- Passing responsibility for the Met Office to the Department for Business, Innovation and Skills provides potential to further enhance existing working relationships and sharing of data between the Met Office and the science base. Relationships are already being developed under the cross-government Living With Environmental Change partnership in the form of focused programmes such as the Joint Weather and Climate Research Programme, among other collaborations.
- Continued development of partnerships across RCUK involving the Met Office will strengthen the flow of evidence and climate services to the policy and business communities, as well as the wider public.

Introduction

1. Research Councils UK (RCUK) is a strategic partnership set up to champion research supported by the seven UK Research Councils. RCUK was established in 2002 to enable the Councils to work together more effectively to enhance the overall impact and effectiveness of their research, training and innovation activities. Further details are available at www.rcuk.ac.uk.

2. This evidence is submitted by RCUK on behalf of the Research Councils listed below and represents their independent views. It does not include, or necessarily reflect the views of the Knowledge and Innovation Group in the Department for Business, Innovation and Skills (BIS):

   Natural Environment Research Council (NERC)
   Science and Technology Facilities Council (STFC)

Responses to Questions

Question 1. How effectively is the Met Office fulfilling its Public Weather Service remit?

3. The Met Office is very effective in fulfilling its Public Weather Service (PWS) remit. The quality of Met Office forecasts for the public compares very well with similar provision in other countries.

4. There are some critically important applications such as hazard prediction, for which advances through coordinated research would benefit the PWS. For example:

   - Forecasting of low cloud (especially in summer) and fog/frost (especially in winter);
   - Medium range forecasts (1-4 weeks) which could have positive economic impact for UK businesses and is highly relevant to certain hazard mitigation issues (such as flood defences or snow clearing infrastructure);
   - Very short range (up to 6 hours) warnings of severe weather.

5. The Flood Forecasting Centre[1] and the Scottish Flood Warning Service, where the Met Office are working jointly with the Environment Agency and the Scottish Environment Protection Agency respectively, effectively implement the Pitt Review[2] with regard to integrated working, forecasting and modelling. Both services use the NERC Centre for Ecology and Hydrology (CEH)[3] Grid-to-Grid model[4] as the main hydrological model underpinning flood warning and forecasting. The National Centre for Ocean Forecasting (NCOF)[5] relies on the expertise of several NERC marine research centres working in partnership with the Met Office to provide services including storm tide forecasting.

6. The current state of science in meteorological forecasting is driven by emerging requirements for higher resolution i.e. more localised forecasts, the development of larger supercomputers and the need for long-range or seasonal forecasts for economic and hazard mitigation purposes. In addition, new observational technology, especially using satellites, creates new challenges associated with making best use of the potentially overwhelming volumes of data in computational forecasting models. The Met Office is in the leading group of international organisations addressing this science. These are extremely challenging areas and we welcome the recognition given to these areas in Met Office science strategy.

7. Through the World Meteorological Organization, the Met Office has responsibility for the UK's international commitments to share the observational data used for weather forecasting, which it fulfils.

8. The Met Office meets it requirement to provide public access to library services and to historic data. Where data is concerned, a significant part is provided through the British Atmospheric Data Centre (BADC)[6] which is managed as part of NERC's National Centre for Atmospheric Science (NCAS)[7]. This external collaboration is a highly cost-effective way of meeting and exceeding, statutory requirements. The Met Office provides much of its data sharing with the wider research community and beyond, nationally and internationally through this mechanism.

9. The potential for sharing data could be maximised by reduced licensing constraints and electronic access by researchers to library holdings could also be enhanced.

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[1] http://www.metoffice.gov.uk/publicsector/hazardmanager
[2] http://www.environment-agency.gov.uk/research/library/publications/33889.aspx
[3] http://www.ceh.ac.uk/
[4] http://www.ceh.ac.uk/products/publications/River-Flooding-GtoG-Model-Impact.html
[5] http://www.ncof.co.uk/
[6] http://badc.nerc.ac.uk/home/index.html
[7] http://www.ncas.ac.uk/

Question 2. Is the Met Office's Science Strategy 2010-15 robust and achievable and how will the strategy help to deliver a better service?

10. The strategy addresses key areas of potential science development and gives a good overall description of the broad scientific challenges. The four science imperatives represent critical and challenging issues in the areas of weather and climate prediction. The research has great potential to deliver improvements in the accuracy of weather forecasts and the trustworthiness of climate predictions. If implemented appropriately, we have high confidence the science strategy will have a positive impact on future weather and climate service provision.

11. The fact that the UK enjoys a world leading position in climate science is substantially attributable to the work of the Met Office, in collaboration with NERC and RCUK.

12. Specific strengths of the strategy include:

- The emphasis on increasingly higher resolution modelling. For example, finer resolution models are required by hydrologists for flood management, water resources planning and climate impacts assessment;
- The emphasis given to building stronger partnerships;
- The restructuring around weather, climate and foundation science (which the Met Office supports to improve its operational weather predictions and deliver advice to help customers with their climate related policy and business decisions) emphasises that much of the science is common to both weather forecasting and climate research;
- Explicit recognition of the increasing importance of international cooperation;
- The proposals to allow more creative freedom for Met Office scientists, the establishment of 'Expert Scientist' and 'Research Fellow' roles, with the need to develop a much stronger capability in computational science and software development.

13. There are some areas where the strategy could be improved, in particular:

- In climate, the science that is required to deliver robust adaptation could be developed more fully, for example, by explaining more clearly the role of the Met Office in relation to other critical partners. This science involves understanding climate change and its impacts on the regional and local scales that are critical for adaptation planning and policy. The importance of attribution is rightly highlighted, but there are numerous challenges, many of which are multidisciplinary. This is an area where the further development of collaborations with NERC, RCUK, LWEC and international partners is particularly important. In addition, in this area, the strategy could be clearer where its priorities in this area lie – locally (UK), regionally (Europe) or globally - and how priorities will be determined;
- The international strategy is very important, since the climate change adaptation challenge will require resources (e.g. in high performance computing) beyond those available in the UK alone; in this area, the Met Office has made significant progress in recent years. The importance of European collaborations is explicitly recognised and the aspiration to take a greater leadership role in Europe is identified. However, there is still a lot of work to do and the Met Office, NERC and the UK as a whole should listen to and collaborate with our natural European partners, as well as seek to provide leadership;
- The Met Office can contribute significantly to space weather prediction as proven providers of high quality forecasting services however the strategy makes no mention of Space Weather. The Cabinet Office has recently endorsed the formation of a

Space Environment Impact Expert Group and Space Weather is an area where collaboration is required;

- The approach to model evaluation (e.g. comparing with observations) could be more clearly explained. This is particularly important when a model is being used for many different purposes, as at the Met Office (see paragraph 17). Modelling must be backed up by long-term measurements such as those that are carried out by the NERC marine and earth observations community;
- The Research Strategy recognises the importance of improving the robustness of radar rainfall estimates for weather forecasting but not explicitly with regard to its potential great value as an observation product for use in flood modelling and forecasting;
- The strategy contains a series of "recommendations" rather than a description of what will be done. In this respect it has something of the feel of an internal recommendation to the Met Office board rather than a set of goals towards which the Met Office is committed. Implementation is only addressed at a very high level.

14. Whilst noting the Met Office Science Strategy parallels aspects of the NERC and NERC-NCAS strategies[8], we would have appreciated a greater opportunity to be consulted on its development.

Question 3. What are the roles of the Met Office's Chief Scientific Adviser and its other senior scientists? How do they provide comprehensive and up-to-date scientific advice?

15. These staff play an active and constructive role in the development of research efforts e.g. by developing and adding value to research programmes of the Living With Environmental Change (LWEC)[9] partnership; a notable example is Dr Richard Wood[10] who currently divides his time between the Met Office role and working as Climate Systems Theme Leader for NERC.

16. It is likely that the influence of these roles will increase in the next few years. Their interactions with the RCUK supported research base are good. Enhancing and taking these collaborations to a more strategic level within the Met Office will add considerable value to RCUK and the Met Office. The Joint Weather and Climate Research Programme is an important step in this direction (see paragraphs 22 to 25).

Question 4. How robust are the models used by the Met Office for weather forecasting, climate predictions, atmospheric dispersion and other activities?

Weather forecasting & climate predictions

17. For short range weather forecasting (1-10 days), the Met Office forecasting system is possibly the world's best. Met Office capabilities in tuning its model to its applications and assimilating data into its model are world leading. The underlying model is internationally competitive but is perhaps where most attention is required. To address this, the Met Office is increasingly using and should continue to use collaborations to take advantage of capabilities developed in other organisations.

18. The Met Office uses the same core model system for climate modelling as for weather forecasting which has served well in terms of international recognition in climate modelling and efficiency of model development. Increasingly climate and Earth System Modelling involves multidisciplinary and "grand challenge" dimensions. This requires

[8] http://www.ncas.ac.uk/strategy
[9] http://www.lwec.org.uk/
[10] http://www.metoffice.gov.uk/research/scientists/cryosphere-oceans/richard-wood

significant change in the approach to partnerships both in the UK and internationally, in particular, to allow the Met Office to access the Earth system science expertise. The necessary changes are underway, and should also involve the UK adopting a more proactive approach to collaboration with international partners, particularly in Europe, to provide and organise the required resources and infrastructure. At a national level, the UK is uniquely positioned to access Earth system science expertise through NERC, because of the range of disciplines and facilities it supports[11] .

19. The Met Office has embarked on a five-year programme with NERC and STFC – the Next Generation Weather and Climate Prediction Programme (NGWCP) [12] - to develop a new dynamical core for weather and climate forecasting models which will be scalable on hundreds of thousands of processors. This approach is essential, enabling efficient exploitation of the next-generation computer architectures required to deliver the next level in supercomputing performance.

Atmospheric dispersion

20. The Met Office uses its own dispersion model for predicting the dispersion of hazardous releases and for fulfilling its role as the Volcanic Ash Advisory Centre (VAAC) for the north-east Atlantic region (including the UK and Iceland). In terms of its ability to predict dispersion, the model is as good as any currently in use and is capable of meeting most needs.

21. The area where modelling capability will continue to need active development, especially as requirements become more diverse, is in representation of physical and chemical processes; this is an area of rapid international development and where NERC-NCAS concentrates considerable expertise and investment. Traditionally atmospheric chemistry is not an area where the Met Office has had major expertise; collaborations are developing and should be expanded to keep this activity competitive.

Question 5. How effectively does the Met Office coordinate its activities with government departments, non-departmental public bodies, the UK research base and its international counterparts?

22. There are numerous examples of well established, effective collaborations between the Met Office and RCUK supported research base involving joint access to and exchange of models, data, expertise and facilities. These partnerships present a huge opportunity for the UK in terms of providing accurate public services including response to emergencies, commerce and scientific research. Ongoing effort to strengthen existing and develop new joint initiatives will ensure the UK gains increasing benefits from investment in the Met Office and the Research Councils.

23. The Joint Weather & Climate Research Programme (JWCRP) [13] is a joint activity between the Met Office and NERC critical to ensuring the UK maintains and strengthens its leading international position and competitive advantage in weather and climate science, and forecasting and provision of advice for policy. This programme is part of LWEC.

24. The JWCRP has the following objectives:

- To ensure the UK has access to internationally competitive tools and infrastructure for maintaining its world-leading national capability in observing, understanding, modelling and predicting weather, climate, and their impacts.

[11] http://www.nerc.ac.uk/about/work/mission.asp
[12] http://www.nerc.ac.uk/research/programmes/ngwcp/
[13] http://www.jwcrp.org.uk/

- To enable closer collaboration between NERC and the Met Office by working to eliminate existing barriers, to strategically align more closely their respective research activities, and to ensure effective participation in relevant new research programmes from both organisations.
- To propose new activities to address critical gaps in the existing national portfolio of weather and climate research and to be actively involved in promoting and developing those activities.
- To develop mechanisms to promote the more effective translation of research and development into improved weather and climate forecasts.

25. These objectives are being addressed by a JWCRP science strategy, based on the existing science strategies of the two organisations.

26. The JWCRP helps the Met Office and NERC work together on major infrastructure investments, and enables both organisations to demonstrate the optimal and efficient use of resources. For example, NERC and the Met Office jointly own and manage the MONSooN supercomputer[14] and the Facility for Airborne Atmospheric Measurements (FAAM) that operates a BAe-146 research aircraft which are used to support the JWCRP science strategy. Joint ownership and management of the MONSooN supercomputer is helping exchange of large datasets between the Met Office and NERC. Development projects in both weather and climate modelling including the joint implementation of a national Earth-system modelling strategy, are also in progress and further integration of research observations between the Met Office and NERC are planned.

27. The closer working between the Met Office and NERC has had short term benefits as well as creating potential for longer term gains. For example, facilities and staff expertise were jointly used to great effect following the Eyjafjallajökull Icelandic volcano emergency. Independent confirmation by NERC-NCAS of Met Office volcanic ash dispersion forecasts was cited by the CAA as one of the reasons that they were able to bring forward new procedures for flying through ash[15]. NERC-BGS played a major part in coordinating the contributions of the geological community. Following the Grimsvötn eruption in May 2011 the Met Office and NERC-BGS were in contact and working together within an hour of the eruption. NERC-NCAS is leading an international effort, with strong Met Office support, to improve the availability and quality of volcanic ash data used in Met Office dispersion modelling. In the longer term, the JWCRP will help facilitate collaboration which has hitherto been more challenging.

28. Recently, the World Meteorological Organisation has led the development of a "Global Framework for Climate Services" (GFCS), which identifies a very wide range of needs and opportunities in respect of climate information. The Met Office, in collaboration with NERC, submitted a UK vision to the Task Force that developed the GFCS, in which they stated their willingness to take a leading role in this important global initiative. The need for effective multidisciplinary partnerships is a key feature of the requirement in this area. For example, the US National Oceanic Atmospheric Administration report Building Strong for Tomorrow[16] recommends strengthening coordination to bring together organisations that will contribute to climate service. Through partnership initiatives such as the JWCRP and LWEC, the UK is very well placed to play a world leading role in these developments.

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[14] http://www.jwcrp.org.uk/infrastructure/monsoon.asp
[15] http://www.caa.co.uk/docs/2011/Teleconferences%20log.pdf
[16] http://www.napawash.org/publications-reports/building-strong-for-tomorrow-an-independent-assessment-and-recommendation-for-the-organizational-design-of-the-national-oceanic-and-atmospheric-administration-noaa-climate-service/

29. A large part (c. 50%) of the research programme of NERC-NCAS is carried out in collaboration with the Met Office. There are good collaborative initiatives between the Met Office and NERC research centres on areas outside of research. For example:

    - The Natural Hazards Partnership (NHP), led by the Met Office, was recently created with the encouragement of the Cabinet Office and the Government Office for Science. It involves thirteen collaborating government agencies including four NERC research centres, Ordinance Survey, the Environment Agency and the Health Protection Agency. It is already providing Government with valuable coordinated advice through a single point of contact on a range of natural hazards driven by extreme weather including floods, droughts, wildfires and landslides.
    - The Environmental Science to Service Partnership, chaired by the Met Office, is aiming to deliver societal impacts and benefits through collaboration between its members (Met Office, Ordnance Survey, Environment Agency, NERC-BGS and NERC-CEH) in the field of environmental service provision. A pilot study into response to extreme drought in the UK is underway.

30. The Met Office contributes to the work of the government's Marine Science Co-ordination Committee (MSCC), with senior staff representing the Met Office on the main Committee, the Science Alignment Working Group, and Long Term Observations Working Group. Outside of the MSCC Met Office staff contribute to working groups on Underwater Noise, the OSPAR convention, Ocean Processes Working Group, and the UK delegation to the UNESCO Intergovernmental Oceanographic Commission.

31. Others important collaborations out outlined at paragraphs 5, 8 and 19.

Research Councils UK

September 2011

Written evidence submitted by the Government (MO 14)

The Prime Minister announced on 18 July 2011 that responsibility for the Met Office would pass from the Ministry of Defence to the Department for Business, Innovation and Skills. The Met Office is a trading fund, operating as a self-contained commercial entity within BIS. The Minister responsible for ownership of the Met Office is now Edward Davey MP; with the Rt Hon David Willetts MP responsible for the customer functions, including its wider scientific role, and the customer for the Public Weather Service, receiving advice from the Public Weather Service Customer Group (PWSCG). The PWSCG commissions weather services on behalf of government and the UK public.

This memorandum draws on advice from the Public Weather Service Customer Group, chaired by Nick Baldwin and from the Government Departments which work with the Met Office or use its outputs. The Met Office will be submitting a separate memorandum to the Committee.

The Met Office is a major national asset. It is widely recognised as one of the leading weather and climate forecasting centres in the world and has provided weather forecasting and related services for the UK for over 150 years.

The Public Weather Service (PWS) provides free-at-the-point-of-use weather information and severe weather warnings for the UK public, including the general public and the resilience community who act on their behalf to allow them to make informed decisions to plan day-to-day and longer-term activities. The PWS also provides research and development activities to deliver required improvements to PWS forecast and warning services; it meets international commitments on behalf of UK Government and it provides underpinning data for stakeholders.

Funding for the PWS comes from four sources:

a. Through BIS (formerly MoD) on behalf of Government;
b. Civil Aviation Authority on behalf of the civil aviation community;
c. Maritime and Coastguard Agency on behalf of the marine community; and
d. From other funding providers such as EU and NERC for specific projects and activities.

The price of the PWS to the PWSCG in FY11/12 (i.e. a. above) is £68.1 million. The additional lines of funding (b.-d.) increase this to £93.4 million. This accounts for approximately half of Met Office annual revenue.

In addition, based on the quality of its science and citations, the Met Office Hadley Centre (MOHC) – the centre within Met Office dedicated to climatology research - has been recognised as the leading geophysical institute in the world[1]. Recent reviews of the MOHC[2,3] recognised its value to Government and affirmed that it *'provides essential and*

[1] *Analysis of geosciences institutes, worldwide.* Times Higher Education Supplement; November 2009 [available on-line at: http://www.timeshighereducation.co.uk/story.asp?sectioncode=26&storycode=409181&c=1]
[2] Lawton (2009) *The 2009 Sir John Lawton Review of the Met Office Hadley Centre* [available on-line at: http://www.bis.gov.uk/assets/bispartners/goscience/docs/s/2009-sir-john-lawton-review-report.pdf]

world-leading climate modelling services to Government, and that it is uniquely placed to do so. It represents a critical national capability, with a central role of meeting the Government's requirements for climate evidence and advice.' The Met Office and its Hadley Centre have delivered scientific credibility and influence for HMG in support of international negotiations and diplomacy. Met Office science is trusted, and the quality of its climate science evidence recognised across the world.

1. How effectively is the Met Office fulfilling its Public Weather Service remit?

1.1. The Public Weather Service (PWS) provides a range of weather information and warnings to enable the UK public to make informed decisions, to optimise or mitigate against the impact of the weather, and to contribute to the protection of life, property and basic infrastructure. The PWS also fulfils international commitments on behalf of the Government.

1.2. The PWSCG acts as the formal customer for the public weather service, on behalf of Government departments, and the general public, for free-at-point-of-use weather services, and ensures that these services are aligned to the operational needs of public sector users of PWS outputs. PWSCG is an independent body that also acts as funding body and guardian of the Met Office's underpinning operational capacity. Background on the PWSCG is attached at Annex A, with its terms of reference attached at Annex B.

1.3. The PWSCG provides independent advice to the Minister for Universities and Science, and as such, its evidence on 'How effectively is the Met Office fulfilling its Public Weather Service remit?' is attached separately from 1.13 to 1.30.

1.4. The Met Office's Public Weather Service (PWS) provides a number of functions for the public (and public sector partners) related to both basic weather information and weather warnings, and also weather influenced events.

1.5. Legislation supporting the Civil Contingencies Act, 2004 requires Category 1 and 2 responders to have regard to the Met Office's duty to warn the public and provide information and advice, if an emergency is likely to occur or has taken place. The Met Office, in our opinion, provides a world class service for emergency planners and policy makers across national and local government, which is the envy of many other countries.

1.6. The Met Office provides the following services under their PWS remit:

- Monthly, 15 day, five day and daily forecasts
- Site specific UK and global forecasts
- A range of other forecasts available via the Met Office website
- A range of specialist forecasts for interest groups (mountaineering, gardening etc.)
- Seasonal Forecasts (3-monthly)

[3] Beddington (2010) *Review of climate science advice to Government and Met office Hadley Centre role, governance and resourcing* [available on-line at: http://www.bis.gov.uk/assets/bispartners/goscience/docs/r/10-1290-review-of-climate-science-advice.pdf]

- National Severe Weather Warning Service
- UK and global response services
- Public weather service advisers
- Hazard manager - a web portal for emergency responders showing current and near future weather conditions
- Forecasting guidance from the Met Office Operations Centre
- General help and advice from the Met Office Customer Centre
- National Meteorological library and Climatological Advice
- Use of the Met Office plane

1.7. Clearly this world class service is extremely wide, covering a wide range of products and customers. Part of the effectiveness of the Met Office is its willingness to go the extra mile for its customers to ensure they have the products they need and best understand. For example the severe weather warnings are now impact-based to assist the emergency planners to understand what 100mm of rain in a 3 hour period actually means. Public Weather Service Advisers officially work a 9-5 day, but during emergencies and at a wide range of weather related events their hours are considerably longer.

1.8. Under its PWS remit the Met Office produces a 'suite' of forecasts to assist emergency planners and the public. The UK is one of only a few countries who ask its Met Office to provide a seasonal forecast, 3 months ahead of the event. In doing so there is a reputational risk for the Met Office. This is very challenging work, and the Met Office continues to work to improve the product.

1.9. The Met Office has one of the largest distribution lists across government and ensures that all weather warnings and information is delivered across the emergency planning community as part of its commitment under the Civil Contingencies Act.

1.10. The Met Office also developed the 'traffic light' system of four colours which highlights the weather maps and advisories it sends out. This simple system alerts emergency planners and the public to the level of risk and certainty of the weather event. This system is now used across all early warnings distributed by the Met Office, Flood Forecasting Centre and Environment Agency.

1.11. VisitEngland - the country's national tourist board – represents the tourism industry. With the weather in Britain one of the most difficult regions in the world to forecast, VisitEngland acknowledge the Met Office as a world leader in weather forecasting that operates a highly complex service internationally.

1.12. However, a criticism VisitEngland hear from the tourism industry, is that, with the climate so highly variable, the presentation of forecasts in the media, especially television forecasts, should be more careful to explain the probability of future events. The key issue, VisitEngland recognise, is the way in which the media communicates this information. For example:

- The current model used by the BBC shows cloud cover predictions and precipitation over the British Isles in some detail – it is felt the level of detail can be misleading because it implies more certainty than there is about future weather events.

- It is felt that weather symbols on maps (TV and newspapers) are too large and do not account for local variations on the ground. They believe that more recognition should be given to the local factors that influence weather patterns and that blanket statements covering whole regions are best avoided, or qualified by a probability component.
- VisitEngland do not believe that televised weather forecasts should be used as a form of entertainment or jokes by either weather forecasters, or more often their link presenters (e.g. BBC Breakfast News). For example, unqualified comments about 'the usual rain over the Bank Holiday,' or other clichés regarding our climate, have a serious economic impact on the tourism industry - impacting on people's decision-making, especially about taking day trips.
- VisitEngland feel that the public relations aspect of weather forecasting should not be the role of the Met Office.

Evidence from the Public Weather Service Customer Group.

Performance standards and measurement including independent surveys

1.13. The PWSCG drives continual improvement and sets challenging performance standards for the PWS by annually setting performance measures and development milestones. These are also negotiated and signed off as part of the annually agreed Customer Supplier Agreement.

1.14. The required standards are a mixture of Met Office measured (but independently audited) targets based on weather forecast and warning parameters (e.g. maximum and minimum temperature, wind speed and direction, rainfall and sunshine) and targets measured by independently undertaken surveys to assess public and responder reach and value.

1.15. In FY 2010/11 the PWS achieved all its Key Performance Indicators.

1.16. Between 2007 and 2010 the PWSCG has commissioned an independent annual survey to gauge public perception of the PWS. Approximately 2000 members of the pubic are surveyed each time. These surveys have found that:

- Nearly all respondents consider forecasts easy to understand
- Nine out of ten think weather forecasts are useful (very or fairly)
- Between seven and eight out of ten think that weather forecasts are accurate (very or fairly)
- Most look at or hear a forecast at least once a day
- Most (83%) consider severe weather warnings to be very or fairly accurate and more (90%) think they are very or fairly useful.

The Public Perception results have remained stable year-to-year.

1.17. The PWSCG also commissions a biannual survey of the emergency responder community; in March 2011:

- Satisfaction with the PWS was found to be extremely high, with 73% saying that they are very satisfied with its services and 97% either satisfied or very satisfied. This represents an improvement from 2008 when 58% were very satisfied.
- Satisfaction with the last weather warning received is also high, with 62% of responders saying that they are very satisfied. This has strengthened since 2008 (56%).
- Satisfaction with the service provided by PWS Advisors remains very high (90% of those who have had contact with them are very satisfied), and has increased since 2008 (86% very satisfied).

The PWSCG has ensured that the PWS is transparent about how well it is performing against targets by requiring the Met Office to publish relevant statistics for temperature, rainfall and sunshine that are updated monthly, on the Met Office web site: http://www.metoffice.gov.uk/about-us/who/accuracy/forecasts.

PWSCG Consultation Activities

1.18. PWSCG undertakes a programme of consultation that enables the PWSCG to make decisions based on end-user benefits, and ensures that all PWS services are aligned to the operational needs of Public Sector users of PWS outputs. As a result of the consultation programme, the PWSCG challenge the Met Office PWS to deliver a set of development milestones. As a result of this the PWS has achieved some major and significant improvements over the past few years including:

- Review and introduction of an impacts based National Severe Weather Warning Service;
- Expansion of the number of site specific forecasts from ~350 to ~5000.
- Increased 'reach' of PWS products and services through the introduction of new channels including for example, an iPhone app, weather widget and mobile service. Information on reach published in the Met Office website shows an increasing trend across each of these platforms over the past 14 months;
- Introduction of 'specialised' forecast services e.g. mountain weather forecasts; avalanche forecasts.

1.19. *In FY 20101/11 the PWS achieved all its Development Milestones.*

Obligations to other customers

1.20. The PWSCG acts as guardian on behalf of public sector users of the Met Office's underpinning operational capability. Thus, it supports Research and Development to ensure the Met Office is able to meet future requirements. In order to ensure continual challenge, the PWSCG annually set key milestones for the research areas of the Met Office. The PWSCG takes advice on the foundation weather science strategy and direction from the Met Office Science Advisory Council (MOSAC) who peer review the Met Office science plans.

1.21. *In FY2010/11 the PWS met 14 out of 18 of its research and development targets.*

1.22. Those targets that were missed were done so deliberately to de-risk delivery of higher priority strategic projects, following consultation and agreement between the Met Office PWS and PWSCG.

1.23. The PWSCG recognises its obligations to ensure the continued availability of research, forecast and observational (Baseline Data) data required by the Met Office in order to deliver services to other Public Sector customers, and to make the same data available to the Met Office's commercial arm and the private sector. It does this by setting annual targets of availability, timeliness and accuracy.

1.24. In FY2010/11 the PWS met all 38 of its Baseline Data targets.

1.25. The PWSCG also ensures that the Met Office provides data to the private sector through a Data Wholesaling Unit, in compliance with Competition Law, the Re-use of Public Sector Information Regulations and the HMSO's Information Fair Trader Scheme. This data is derived from the Baseline Data. The PWSCG requires that the Met Office review and update the catalogue of Wholesale Data annually.

International Obligations

1.26. The PWSCG requires the Met Office PWS to fulfil commitments on behalf of UK Government on 3 designated international bodies:

(i) EUMETSAT
(ii) European Centre for Medium range Weather Forecasting (ECMWF)
(iii) World Meteorological Organisation (WMO)

International subscriptions to the World Meteorological Organisation (WMO), European Centre for Medium-Range Weather Forecasts (ECMWF) and EUMETSAT are funded through the PWS and overseen by the PWSCG. These subscriptions deliver benefits far beyond PWS - through Met Office services to MoD. BIS and others, and through other users of satellite and model data and observations, including academia, other Government Departments and the private sector.

1.27. The PWSCG set and monitor targets to ensure the PWS and wider users and stakeholders receive the best value for membership of the international bodies. The PWS is also required to report to the PWSCG on outcomes of international meetings. For example, it was recently informed on the outcomes of the UK delegation to the WMO Congress where John Hirst was successfully reappointed to the Executive Council and the newly appointed Director of ECMWF will be presenting his strategy and vision for the Centre at an upcoming PWSCG meeting.

1.28. In FY2010/11 the PWS met all its International targets.

Meteorological Library and Archive Service

1.29. The PWSCG require the Met Office to provide a meteorological library and archive service available to anyone with an interest in the weather or climate and an approved place of deposit for meteorological information under the public records Act (1958). This is to enable the general public to research the UK's weather and climatology and to access information that helps the public to understand the science and history of meteorology. There is also a legal requirement handed down to the Public Weather

Service from the Lord Chancellor's office to archive meteorological data on behalf of the UK Public.

1.30. The PWSCG require the library and archive to report on activity each FY. In FY 10/11

- There were 187,270 pages viewed on the Library Catalogue
- Over 99% of a total of 2904 library and archive enquiries were answered within 5 working days
- Customer satisfaction with the enquiries service was high: 3.9/4 rated for speed, relevance of information, and whether customer is totally satisfied with the response.

2. Is the Met Office's Science Strategy 2010-15 robust and achievable and how will the strategy help to deliver a better service?

2.1. Services to government currently make up the majority of Met Office business. The Public Weather Service is the main component of this but other services provided to government include advice on climate science and climate change impacts, advice for informing more specific emergency activities (for example through the Flood Forecasting Centre), and operational advice to the armed forces.

2.2. The core function of the Met Office is weather forecasting. The accuracy of near term forecasting, up to ten days out, is now very high but there is greater uncertainty associated with predictions on longer timescales: monthly, seasonal, decadal and beyond; and particularly with respect to predictions at regional and local spatial scales. Reducing these uncertainties will enable more confident assessments of future weather patterns, including extreme events. More reliable future forecasting would be of great benefit to operational decision-making and resilience planning in a number of sectors, including with respect to our vital infrastructure and resources. HMG's priorities for climate science evidence and advice are well documented in the Government Chief Scientific Adviser (GCSA)'s 2010 review of climate science advice to government[4].

2.3. The context of the Met Office Science Strategy is to develop a seamless approach to weather and climate forecasting. It appears geared towards meeting government needs for more reliable forecasting and assessment of impacts across the full range of time and spatial scales. Delivering improvements in forecast capability requires advances in scientific understanding of how some earth system processes influence our weather and climate, improved representation of these processes in models, and sufficient supporting infrastructure to enable this. We believe the Met Office science strategy provides a generally clear and targeted framework for addressing these issues.

2.4. We recognise that the underpinning observational and supercomputing infrastructure, and scientific knowledge is the same for forecasting across all timescales, from days to centuries, and that synergies and efficiencies can be delivered by co-locating weather and climate services. It is judicious that the Met Office strategy seeks to exploit these

[4] Beddington (2010) *op cit*

as far as possible through an integrated organisational structure and seamless prediction system.

2.5. The need for increased model resolution is a thread which runs throughout the strategy. We understand that, just as the accuracy of weather forecasts is significantly improved by high resolution modelling, so can the regional and local specificity of longer-term climate forecasts be improved. A strong case for continued investment in supercomputing capacity to enable climate models to be run at greater resolution was made in the GCSA's review[5] of HMG's climate science advice needs. This review also recognised the significant near-term costs involved and the need for greater collaboration on supercomputing resources, including internationally, stressing that long term development of modelling capability would likely require a European solution. We welcome the Met Office plans to pursue this as part of their science strategy and we support them in this.

2.6. The challenges which the Met Office strategy identifies are global in nature. Collaboration, both nationally and internationally, and across disciplines, is fundamental to addressing these challenges, and advancing scientific understanding and new research, for example on climate and extreme event attribution. The proposal for stronger partnerships and collaboration is fully endorsed and will be a crucial element of the success of the Science Strategy, although we suggest that the proposed science partnerships should also include representation from government to provide additional context to proposed research programmes.

3. What are the roles of the Met Office's Chief Scientific Adviser and its other senior scientists? How do they provide comprehensive and up-to-date scientific advice?

3.1. The Met Office Chief Scientist (CSc) is part of the network of departmental Chief Scientific Advisers (CSAs) which, under the leadership of the Government Chief Scientific Adviser (GCSA), works collectively to ensure that robust, joined-up science and engineering evidence and advice is at the core of decisions within departments and across government.

3.2. As part of this network the Met Office CSc contributes to discussions on cross-cutting issues, bringing to bear specialist knowledge and also profiting from knowledge exchange with CSAs from other disciplines. Being part of this network helps to ensure the relevance of the science advice provided by the Met Office CSA to government.

3.3. The Met Office CSc also has regular one-to-one contact with the GCSA and departmental CSAs. Met Office scientists at all levels are also in regular – for some departments, daily – contact with departmental science and policy officials, providing high-quality up-to-date science advice to these departments. The Met Office Chief Executive, John Hirst, and his directors, also have good working relations with and are in regular, direct contact with, senior officials of customer departments.

[5] Beddington (2010) *op cit*

3.4. The Science Strategy highlights that the role of the Met Office Science Advisory Committee (MOSAC) will be enhanced in the near future. In considering changes to the remit and terms of reference of MOSAC we would encourage the Met Office to reflect on the independence of the Committee and the Principles on Scientific Advice to Government, noting the revised Code of Practice for Science Advisory Committee (CoPSAC) to be published in the Autumn. This identifies best practice guidelines and provides practical advice on the operation of Science Advisory Committees.

4. How robust are the models used by the Met Office for weather forecasting, climate predictions, atmospheric dispersion and other activities?

4.1. Models are powerful tools to understand future states but all good modelling (climate or otherwise) produces a range of possible outcomes. Ensemble forecasting[6] methods used by the Met Office help provide a better assessment of the uncertainties associated with weather and climate predictions. The Met Office Science Strategy seeks to reduce modelling uncertainties through advancing our underlying scientific understanding and exploring options for increasing model resolution. This will improve the confidence we can have that the models reflect real climate trends and processes well, and provide the best possible input to inform climate adaptation decisions and investments that we need to make in the near term.

4.2. We understand that the formal 'skill' of the Met Office global numerical weather prediction (NWP) model has improved consistently in the past decades and that, for example, the current 3-day forecast is as skilful as the 1-day forecast was 20 years ago, in line with other leading forecasting centres. We also understand that in international benchmarking of the performance of global NWP systems, supported through the World Meteorological Organisation (WMO) and using a range of metrics; that the Met Office is consistently in the top three, alongside the Japanese Meteorological Agency and the European Centre for Medium-range Weather Forecasts.

4.3. Met Office provides the large majority of climate, weather and ocean forecasting and related services required by government. For Defence and the Armed Forces Met Office numerical weather predictions (NWP) have significant use at all levels of military operational planning. At the strategic level, forecasts of seasonal variations allow long term planning, whilst at the operational and tactical levels the current NWP output is required to assess the impact of environmental factors on weapon systems and manpower. Detailed assessments of this impact are required over a timeline of hours, days and weeks and must be updated regularly and, crucially, be within accuracy guidelines agreed between the MoD and the Met Office.

4.4. The MoD has worked in partnership with the Met Office for a significant period of time and has contributed to the development of a variety of meteorological and oceanographic models, used alongside the NWP, to support current and anticipated defence operations. The MoD funds specific nested high resolution models required to support military tasks worldwide, meteorological models to support ballistic and CBRN (Chemical, Biological, Radiological, and Nuclear) downwind messages and dispersion

[6] Ensemble forecasting involves multiple forecast runs with slightly different initial conditions for each, in order to provide a probabilistic assessment of possible outcomes

4.5. DECC and Defra co-fund the Met Office Hadley Centre and climate model development. Climate modelling directly informs government policies on climate change mitigation and adaptation, by providing assessments of the impacts of different levels of atmospheric greenhouse gas emissions nationally and globally to inform planning and policy decisions. The 2009 Lawton Review[7] highlighted a consistency of view across expert contributors to the review that MOHC was one of the leading groups of climate modellers in the world and that it '*worked at the cutting edge in many areas, for example in some areas of Earth Systems' modelling and in decadal prediction'*. We understand that Met Office climate models have performed well in the first three international climate model intercomparison projects (CMIP-1 to CMIP-3)[8] coming 1st, 1st, and 2nd respectively and DECC and Defra are confident that the MOHC's latest earth system models (HadGEM family) will perform well in the current CMIP-5[9] which will be reported on in the IPCC Fifth Assessment Report.

4.6. The Met Office has long been developing a unified modelling system, wherein the same fundamental science and modelling are used across the whole range of forecasting timescales, from hours to centuries (so called 'seamless science' and 'seamless prediction').

4.7. A decade ago, the Met Office invested in the development of a ground-breaking, low-cost, PC-based regional climate model (PRECIS) for use locally, primarily in developing countries. PRECIS remains one of very few such systems and has received considerable approbation from users worldwide. PRECIS-2 is currently being developed with DFID funding.

4.8. Met Office is a designated Volcanic Ash Advisory Centre (VAAC), responsible for monitoring and forecasting the movement and dispersion of volcanic ash originating from volcanoes in the north-eastern part of the North Atlantic Ocean. The Met Office atmospheric dispersion model, NAME, underpins the advice provided by the Met Office in their capacity as a VAAC, and was used to support the work of the Scientific Advice Group for Emergencies (SAGE) in the Volcanic Ash incident in March 2010. Since that time enhancements have been made to NAME's operational functionality to improve the physical basis of ash concentration forecasts. The World Meteorological Organisation (WMO) has also led work to compare the modelling approaches of the nine VAACs[10,11] and this work has shown a high degree of alignment between the top

[7] Lawton (2009) *op cit*
[8] CMIP-1 and CMIP-2 models were used the IPCC 3rd Assessment Report. CMIP-3 models were used in the IPCC 4th Assessment Report
[9] There was no CMIP-4. ***C4MIP*** was intercomparison for fully coupled models with an interactive carbon cycle - hence not relevant here
[10] C. S. Witham, et al (2007) *Comparison of VAAC atmospheric dispersion models using the 1 November 2004 Grimsvötn eruption*, Meteorological Applications, Vol 14 (1)
[11] Ash dispersal forecast and civil aviation 2010, UNIGE - Ash dispersal forecast and civil aviation 2010 - Results

tier models (including NAME) when run with the same source terms[12]. This continuing programme of model inter-comparisons will identify the strengths and weaknesses of different models and drive additional improvements in all models. NAME has also recently been independently reviewed at the request of the CAA[13]. That study, and the work by the WMO, has shown that NAME compares favourably with models used by other international meteorological organisations.

4.9. The Government recognises that the robustness of Met Office models is contingent on the accuracy and adequacy of supporting observational data. Observations directly input to models and to model development (through enhancing our scientific understanding) and are the only means of verifying model outputs.

4.10. A global climate observation system is fundamental to continued improvement in weather and climate forecasting and the 2010 GCSA review[14] confirmed the need for long term high quality observations of the climate system to underpin advances in forecast capability. Arguably, the Met Office is unique in the world in respect of its ability to link analysis of observations and climate modelling and this has been recognised by several independent reviews[15]. We are pleased that the Met Office Science Strategy includes a strategic aim to build appropriate collaborations on observations (for example, of essential climate variables) and we would welcome a clearer view of progress on this.

4.11. Consideration of observational capability was also the primary concern of the recently established Volcanic Ash Observations Review Group, chaired by the GCSA at the request of the Secretary of State for Transport. This group considered the robustness of the Met Office NAME model for predicting the location of volcanic ash and concluded that understanding and improving our knowledge of the source term inputs into NAME was key to reducing the uncertainty in model outputs. This group also agreed that, given the recent independent reviews of NAME, a further review of the model itself was not necessary at this time.

5. How effectively does the Met Office coordinate its activities with government departments, non-departmental public bodies, the UK research base and its international counterparts?

Met Office has a strong relationship both with its sponsoring departments and other key customer departments. A number of examples, which are not exhaustive, are described below. (The Research Councils are providing a separate submission to the Inquiry, which will address how effectively the Met Office coordinates activities with the UK research base.)

5.1. Since its formation in 1990, the MOHC has delivered policy-relevant climate science evidence and advice to HM Government, primarily funded by DECC and Defra and their

[12] It should be noted that the majority of studies have focussed on comparison between dispersion models, rather than comparisons of NAME coupled with different weather prediction models
[13] Review of the Met Office Trajectory and Dispersion Model NAME, Professor David Fowler Centre for Ecology and Hydrology Edinburgh, July 2011
[14] Beddington (2010) *op cit*
[15] E.g. Risk Solutions (2007) Hadley Centre Review 2006 Final Report, a report for MoD/Defra

predecessors and by MoD until 2009. Since the current Climate Programme was set out in 2007, Met Office management has maintained an excellent supplier-customer relationship with DECC and Defra, acting flexibly to deliver research that closely meets departmental needs, as confirmed in the GCSA's review in 2010[16]. Met Office climate scientists at all levels are in daily contact with DECC and Defra officials, providing evidence and advice to inform policy. This interaction has been encouraged, facilitated and strongly supported by senior Met Office scientists and management and is seen by the departments concerned as a critical component of a successful directed research programme.

5.2. In 2009 Defra published the latest UK Climate Projections (UKCP09), based on Met Office world class science, breaking new ground in promoting climate risk assessment to support the UK's preparedness for climate impacts and ensuring climate resilience. The user interface and tools to exploit these sophisticated climate projections have been developed to ensure a close fit with evolving user needs and to stimulate risk assessment in the public sector (central and local), regulated industries and other businesses. Government's own climate change risk assessment (CCRA), to be published in early 2012, is built on UKCP09. This directly supports Defra's objective of building resilience to climate change. Keeping the advice in the UKCP products up to date is likely to be important for future CCRAs.

5.3. The Met Office Hadley Centre leads a consortium of UK research institutesto deliver the Avoiding Dangerous Climate Change (AVOID) programme. AVOID was set up in 2009 specifically to provide policy-relevant scientific and technical evidence to HM Government (DECC and Defra in particular) to inform national and international strategies on mitigation and adaptation. The findings of the programme have been used inform the UK positions ahead of recent UN Framework Convention on Climate Change (UNFCCC) Conferences of Parties and has contributed to international reports such as those by the EU[17] and UNEP[18] on the "emissions gap".

5.4. Promoting awareness of global climate impacts with other governments around the world is a key part of HMG's strategy to change political conditions in order to promote a global legally binding treaty on emissions reduction under the UN Framework Convention for Climate Change (UNFCCC). The Met Office provides support on accessing, understanding and interpreting the latest climate science which allows the FCO to talk with an authoritative voice on climate change from a sound scientific evidence base. The Met Office has also been able to provide unbiased scientific answers where there is disagreement on the basic issues of the science which have proved sticking points in discussion. Met Office climate scientists have accompanied FCO representatives on country visits, speaking at events organised by the FCO to raise awareness and engagement on climate change issues.

[16] Beddington (2010) *op cit*

[17] Fee *et al*. (2010): Scientific Perspectives after Copenhagen: Information Reference Document. European Union.

[18] UNEP, 'The Emissions Gap Report: Are the Copenhagen Accord pledges sufficient to limit global warming to 2°C or 1.5°C?'.

5.5. The Met Office has undertaken a range of studies for informing discussion, such as a report on the vulnerability of global energy infrastructure to climate change and a series of summaries of the impacts of climate change for key FCO priority countries. The Met Office communicates the often complex and uncertain science of climate change in a way that is most value to the FCO. This is to enable non-specialists to engage with the science and set a baseline of understanding of the impacts of climate change, from which UNFCCC negotiations can be undertaken. This work often communicates research done by the Met Office on the sensitivity of the climate to human activity, such as the "4 Degree Map"[19] which has been an extremely useful influencing tool worldwide.

5.6. FCO has a keen interest in Met Office studies conducted for other Government departments, such as the recently completed reports prepared for the Government Office for Science Foresight project on the International Dimensions of Climate Change. The project on climate impacts which the Met Office is implementing for DECC is a key part of HMG preparations for the UNFCCC Conference of Parties in Durban in November.

5.7. The Met Office has consistently provided high quality and responsive scientific advice and support to the GCSA-chaired Scientific Advice Group in Emergencies (SAGE), including provision of advice to the first Fukushima SAGE on the 13th March with only an hour's warning that a SAGE was being formed. During the Fukushima emergency a 24 hour emergency response mechanism was established which would not have been possible without the dedicated support provided by Met Office scientists. This mechanism enabled advice on the potential consequences of a release of material from the Fukushima plant to be provided to UK citizens in five Japanese cities within half an hour of release, based on pre-calculated dose rates and predicted weather conditions.

5.8. Both DECC and the energy industry found the Volcanic Ash Advisory Centre to be of great assistance in ensuring the safety of helicopter operations at offshore oil rigs during the Icelandic eruptions last year. The centre also provided good data quickly, to assist the department in assessing the potential risk to the UK energy network through volcanic ash accumulating on overhead lines.

5.9. The MoD has maintained a close working relationship with the Met Office through Defence Intelligence. The framework for this partnership is a Customer Supplier Agreement (CSA), supported by annual Service Definition Agreements (SDA) covering the provision of meteorological and oceanographic support to Defence. This is a detailed agreement specifying the support requirements for specific defence roles, exercises and overseas operations, training and the infrastructure required to deliver this support. MoD research requirements are progressed through the SDA framework after consultation within specific defence areas and where appropriate with NATO partners. The pull-through of this research is monitored by Defence Intelligence to ensure value for money is achieved.

[19] http://www.fco.gov.uk/en/global-issues/climate-change/priorities/science/

5.10. The move of the Met Office from MoD to BIS in July creates a different working relationship between MoD and Met Office that will be governed by a new Service Level Agreement (SLA), however, it is anticipated that this move will not reduce the outputs and services already provided to MoD. In order to ensure a close liaison is maintained in the future, it is recommended that an RN OF5 (Meteorological Specialist) post is established within the Met Office in Exeter to firstly, balance the Met Office post currently funded by MoD within DI ICSP and secondly, to add continued support to the valued and extensive contribution the Met Office makes to Defence.

5.11. The Met Office already has very strong links with the climate and earth system science academic community in the UK and abroad. DECC and Defra have strongly encouraged MOHC to build links with NERC and other UK institutions over the past few years and are pleased to see these have delivered new, world class research and improved climate projections. For example, since April 2010, MOHC have published 165 peer-reviewed papers based on Climate Programme research (many in very high profile journals) and in 2009-10 approximately 80% of their papers were co-authored by non-Met Office staff. This proportion has been steadily increasing since the Climate Programme started.

5.12. The Met Office has also conducted research projects funded or partly funded by the FCO and DfID, to build capacity within countries, or to help further the dialogue on climate change issues within that country. Examples of this include: the Met Office PRECIS regional climate model given to countries to enable them to run their own climate change experiments; research in collaboration with counterparts in Brazil to understand more about regional climate change in that area; research in collaboration with Russian climate scientists to improve the representation of Russian climate within climate models; a project on climate change and security in the Sahel, jointly funded by the French Foreign Ministry and undertaken with OECD. The Met Office has an excellent reputation worldwide and has a strong network of contacts with counterparts overseas.

5.13. We understand that several other major bilateral collaborative links have now been forged by the Met Office, for example with Australia, New Zealand, Korea and Norway, among others, which are already delivering improved modelling systems. In 2010, the Australian Bureau of Meteorology implemented the Met Office's Unified Model to deliver its national weather forecasts and a dramatic performance improvement (as measured by skill metrics) has already been achieved. The Korean Meteorological Administration (KMA) also used the Unified Model for their national weather forecasting and the Met Office and KMA will implement a joint seasonal forecasting system in 2012. Further evidence of strong international collaboration, encouraged and supported by DECC and Defra, is MOHC's increasing work with UK, U.S. and other partners in the Attributing Climate Extremes (ACE) group which is building new and robust methods for attributing extreme weather and climate events.

5.14. The Defence Oceanographic programme significantly benefits from the Met Office's collaboration with national and international partners, most notably through the National Centre for Ocean Forecasting (NCOF), the MEMO consortia and European Commission research projects. The continued development of Global and nested

higher resolution models has supported the strategic deployment of the nuclear deterrent, Mission Support and Planning (MSP), Mine Counter Measures (MCM) and Anti Submarine Warfare (ASW). Continued development of models will support Tactical Decision Aids and acoustic range prediction models as directed by MoD policy.

5.15. As Earth systems models improve there are new opportunities to increase engagement with academics in the impacts and biophysical modelling community. For example, understanding and reconciling differences between integrated Met Office models and other specific impacts from elsewhere will improve the science of both and increase consistency of advice for decision-makers. Some work is already underway in areas such as water availability and crop modelling and is highly promising. There may also be particular benefits from working with more impacts specialists with expert local knowledge in particular regions around the world. Further increasing data availability and accessibility will support collaboration efforts. There could also be opportunities for developing new climate services by examining best practice in how forecasts and advice are delivered and used around the world.

5.16. The climate system has no national boundaries and we believe that continued collaborations will improve understanding of crucial phenomena such as ENSO (the El Nino Southern Oscillation), and eventually lead to significant benefit and added value to the UK. We continue to encourage and support the Met Office in building strong collaborations in the UK and internationally to deliver increased scientific capability and knowledge exchange.

5.17. Following the flooding in 2007 Sir Michael Pitt's Review recommended that the Met Office and Environment Agency worked much more closely together to ensure that future flooding events may be better predicted and avoided. The Met Office and the Environment Agency set up the Flooding Forecast Centre, (FFC), staffed by members of both organisations. They have over the past couple of years developed the centre in its premises in the Met Office at Exeter. Daily flood forecasts are produced and distributed and the two organisations work extremely closely and well together. The FFC have also taken responsibility for the Storm Tide Forecasting Service. Using Met Office forecasts of coastal water levels and weather forecasts the FFC alerts the EA and SEPA to the risk of coastal flooding.

5.18. Additionally, the Met Office has established the Natural Hazards Partnership, with support from the Cabinet Office and GO-Science. The Partnership brings together the leading public sector environmental agencies to share expertise and develop multi-hazard services to reduce the impact of natural hazards on the UK. Within a year of the Partnership being established, it has already piloted a multi-hazards warning service and the expertise is being integrated into the Cabinet Office National Risk Assessment process to ensure the best use of scientific evidence in planning and preparing for natural hazard events.

5.19. The Met Office has always worked very closely with a variety of other government departments. The Met Office has a role in forecasting the spread of airborne diseases such as foot and mouth and blue tongue for DEFRA. Numerical Atmospheric Modelling Environment (NAME) can be run using localised weather data, and using Geographic

Information System (GIS) and Ordnance Survey mapping systems overlaid to show possible spread of the disease.

5.20. In collaboration with the Department of Health the Met Office have helped produce the Heatwave plan for England and Wales. This plan, based on 4 levels and a series of regional threshold temperatures ensures that hospitals and all medical practitioners receives information about potential hot weather and its potential to cause excess deaths. At Level 4 the nature and length of the heatwave would be such that a wide range of government departments would be affected. DH and the met Office are now working on a Cold Weather plan for the UK based on a similar set of principles and warning levels.

5.21. In the event of an incident caused by hazardous chemicals local fire or police services can contact the Met Office and request a CHEMET report. These chemical meteorology reports include plume modelling and weather forecast information. The development of this service has involved the Met Office working closely with the Fire Service and DCLG.

5.22. During the Buncefield fire and the emergency that followed, the service provided by the Met Office to other government departments was invaluable. As well as the CHEMETs provided, the Met Office plane flew through the plume to collect samples for analysis. As the plume moved towards the near continent the Met Office provided modelling of where the plume might travel so the UK could fulfil its international obligations to inform its partners of potential danger.

5.23. The Volcanic Ash Advisory Centre advises the Civil Aviation Authority about ash in the atmosphere, usually, but not exclusively, from Icelandic volcanoes. This work is carried out on behalf of the Department for Transport (DfT). In the recent Icelandic volcano eruptions the Met Office have worked very closely with DfT to provide ash plume monitoring. The Met Office contacts with the Icelandic Met Office have proved invaluable.

5.24. During major emergencies or incidents the Met Office has been called upon to provide staff to attend strategic command meetings both in COBR and the Scottish Government Emergency Room. For the first time during the Icelandic volcano emergencies, the Met Office embedded a member of staff at the Cabinet Office, and this was greatly appreciated, both by us and other government departments involved.

5.25. A member of the Met Office was also embedded in DfT during last winter's severe weather to ensure that DfT received the most up to date information to assist in modelling for salt supplies across the UK. This proved to be an important and valuable service.

5.26. The Met Office also works with DECC and DEFRA on the response to small scale nuclear incidents. This followed the Chernobyl incident in 1988. The Radioactive Incident Monitoring Network (RIMNET) enables any increase in radiation levels across the UK to be detected and automatic alerts generated.

5.27. VisitEngland have had discussions with Met Office about sharing research opportunities. For budget reasons this has not been possible, but they are open to future possibilities should the financial position change.

5.28. The Government's view is that the Met Office works very effectively with a wide range of departments and continues to seek to improve the service it provides to its customers.

Department for Business, Innovation and Skills
September 2011

Annex A

Background on the Public Weather Service Customer Group

PWSCG is responsible for setting the requirements and outputs of the PWS provided by the Met Office, supporting research and development to meet future requirements, and providing independent advice and recommendation to the Minister for Universities and Science (formerly the Under Secretary of State for Defence (Minister for Veterans)) to enable formal agreement of the PWS Customer-Supplier Agreement (CSA).

In addition to detailed definitions of the PWS outputs, the annually negotiated and agreed CSA specifies performance measures and standards, international commitments and the service price, including year-on-year efficiency savings.

Membership of the PWSCG consists of:

- Independent Chair – currently this position is held by Nick Baldwin
- Cabinet Office Civil Contingencies representative
- Association of Chief Police Officers representative
- Chief Fire Officers Association representative
- Local Government Association representative
- Scottish Executive Government representative
- Welsh Government representative
- Environment Agency representative
- Highways Agency representative
- Independent member representing the UK public

The PWSCG meets quarterly to provide strategic direction and challenge to the Public Weather Service. The group is supported by a secretariat which monitors and challenges PWS performance on a monthly basis and is currently advised on reach by the Editor of BBC Weather.

The PWSCG is responsible for defining the scope of the PWS remit (which defines the Met Office Public Task) which is to:

• produce weather forecasts which help the UK public make informed decisions about day-to-day activities;
• warn people of extreme weather to mitigate its impacts—contributing to the protection of life, property and infrastructure;
• improve weather and climate predictions through research;
• fulfil international commitments on behalf of the UK Government; and
• provide public access to historic weather information via our Library and Archive and climatological records.

The PWSCG undertakes a programme of consultation to ensure that any changes that are made to current or future PWS outputs are based on independent consultation and will withstand a robust degree of external challenge. In addition, the PWSCG ensures availability of research, forecast and observational data required by the Met Office in order to deliver services to other Public Sector customers, and to make the same data available to the Met Office's commercial arm and the private sector. Finally, the PWSCG requires the PWS to fulfil commitments on behalf of UK Government on 3 designated international bodies. Details on how well the PWS meets these requirements are provided from paragraphs 1.14 to 1.31 in this memorandum. Further detail can be found in the PWSCG Annual Report for financial year 2010-11: http://www.metoffice.gov.uk/media/pdf/m/5/PWSCG_Annual_Report.pdf.

Annex B

Terms of Reference of the Public Weather Service Customer Group (PWSCG)

Note: These terms of reference are in the process of being updated for formal adoption as part of the change of PWSCG ownership from MoD to BIS.

Purpose

The PWS provides a coherent range of weather information and weather-related warnings that enable the UK public to make informed decisions in their day-to-day activities, to optimise or mitigate against the impact of the weather, and to contribute to the protection of life, property and basic infrastructure.

The PWS also fulfils international commitments on behalf of UK Government, and provides research, and forecast and observational data which are essential inputs to a wide range of Met Office services.

The PWSCG acts as the customer on behalf of the public for free-at-point-of-use weather services and ensures that these services are aligned to the operational needs of Public Sector users of PWS outputs. It also acts as guardian on behalf of public sector users of the Met Office's underpinning operational capability. It is responsible for setting its requirement and specifying its outputs, supporting research and development to meet future requirements, and providing independent advice and recommendation to the Under Secretary of State for Defence (Minister for Veterans) to enable formal agreement of the PWS Customer-Supplier Agreement.

Members

- Independent Chair

- Cabinet Office - Civil Contingencies
- ACPO – Association of Chief Police Officers
- CFOA - Chief Fire Officers Association
- Local Government Association
- Scottish Executive Government
- Welsh Assembly Government
- Environment Agency
- Highways Agency
- Independent Member

Advisors
- Editorial Manager, BBC Weather Centre
- Head of PWS CG Secretariat
- PWS CG Secretariat Support Manager

Responsibilities
Specific responsibilities include:
- Setting the current and future requirement of the PWS and specifying its outputs
- Ensuring appropriate inclusion of international commitments within the PWS
- Conducting or commissioning appropriate consultation and market research to ensure
  - representation of interests of professional partners and public users of the PWS
  - representation of interests of public sector customers for whom the Met Office provides direct services using a defined baseline of PWS capability and data
- Conducting or commissioning appropriate financial or technical scrutiny to ensure
  - delivery of value for money in relation to the quality of service required
  - efficiency
- Setting performance indicators and associated targets
- Robustly monitoring performance and delivery against specified outputs
- Agreeing funding for services based on past performance and present requirements
- Providing support for Met Office bids for additional funding from alternative sources, as appropriate, to enable further development of the Service
- Considering and endorsing proposals for in-period changes within the PWS as required
- Maintaining appropriate level of communication with the Met Office Executive and Chair Met Office Board
- Maintaining appropriate level of communication with MoD DG Finance or his representative

Relationships and lines of communication
The Secretary of State for Defence is the Minister responsible for the Met Office and is accountable to Parliament for the Trading Fund's policy and operations. The Chief Executive of the Met Office is personally accountable to the Secretary of State for the effective and efficient management of the Trading Fund and for achieving the Aims and Objectives set out in the Framework Document. He is also appointed the Accounting Officer for the Trading Fund.
The Under Secretary of State (Minister for Veterans) acts on behalf of the Defence Secretary as Owner, and is advised by the Met Office Owner's Council. It is the means through which the Trading Fund reports performance and seeks top level guidance from

the Ministry. The Chairman of the PWSCG reports to the Secretary of State for Defence through MoD DG Finance or his representative.
PWSCG is responsible for proposing changes to these Terms of Reference to the Minister through MoD DG Finance or his representative.

Group Members
The Chairman will be a public appointment by MoD DG Finance on behalf of the Minister. Other Members will be drawn from the main Public Sector users of PWS outputs, together with public appointment(s) by the Chairman as appropriate to represent public users of the PWS. Head of the PWSCG Secretariat will act as advisor to the PWSCG and, as a representative of the funding Department will provide assurance to the budget holder regarding appropriate use of MoD funds. In addition, a representative from a nominated broadcaster (currently BBC) will be assigned to the Customer Group to advise on output specification and effective communication of the PWS message and inform the PWSCG on public perception of the PWS outputs, based on feedback from viewers and listeners.
The Chairman and public appointee(s) will be remunerated by MoD through the PWSCG Secretariat, contracted for a fixed term.

PWSCG Chairman
The Chairman has responsibilities additional to those of the group. He/she is the single point within the PWSCG accountable to the Secretary of State for Defence, and is responsible for:

- Chairing the PWSCG
- Ensuring the proper execution of the PWSCG ToRs
- Reviewing and, if appropriate, seeking amendment to the PWSCG ToRs
- Establishing and maintaining the most appropriate funding mechanism to fulfil the PWSCG ToRs
- Formal approval of the PWS Customer-Supplier Agreement (CSA)
- Negotiating funding from MoD through the STP process
- Negotiating and agreeing the PWS price annually with the Met Office
- Confirming to the Custodian of the PWS funds that invoices from the Met Office are consistent with the agreed output price
- Ensuring that PWS funds are spent with due regard to economy, value for money and the Government's drive for efficiency
- Establishing, maintaining and documenting the most appropriate PWSCG process to fulfil its ToRs
- Building and maintaining links with appropriate user representatives to inform the development of future output definitions
- Raising the profile of the PWS within government
- Increasing the integration of the PWS within broader government initiatives
- Increasing the impact of the PWS on beneficial outcomes for the UK
- Identifying and supporting, as appropriate, bids to alternative funding sources
- Providing reports to the Met Office Board and Departmental Owner
- Providing a focal point for all PWSCG correspondence

The Chairman will appoint a deputy to act on his/her behalf in his/her absence.

Secretariat
The PWSCG will be supported by a Secretariat staffed by officials provided by the MoD. The

Secretariat will be a dedicated resource and strongly support the Chairman and PWSCG, in particular:

- Consulting widely with public and professional users of the PWS
- Liaising with other government stakeholder interests in the PWS
- Drafting output requirements for incorporation in the annual review of the PWSCG CSA and formally improving the Service Definition Annexes
- Ensuring appropriate financial provision
- Liaising with the Met Office and monitoring of performance against agreed KPIs and targets.

Formal Meetings

The PWSCG will normally meet at least twice a year to conduct its formal business. Other ad hoc meetings may be called by the Chairman as required. A formal meeting of the PWSCG will be considered quorate provided no more than two Members are absent. Where necessary, voting will be on a two thirds majority basis and the Chairman will have the casting vote.

Duration

The PWSCG is established on an on-going basis until no longer required, when it will be dissolved on instruction from the Minister.

Written evidence submitted by the Department of Meteorology, University of Reading (MO 15)

1. Submitted by

Department of Meteorology
University of Reading

2. Executive Summary:

The effective delivery of the Met Office Public Weather Service requires a strong science base. There is a need for cutting-edge scientific research to respond to the changing demands of the Public Weather Service. The UK research community is world leading in the atmospheric science. The Met Office has a robust strategy that emphasises partnership with the wider UK research base to deliver this new science. The Department of Meteorology, University or Reading, is very strongly integrated into this strategy, and many of its research projects have direct connections with Met Office scientists and help to deliver the science to enable a better Public Weather Service.

3. Brief Introduction to the submitter:

The Department of Meteorology, University of Reading, is internationally renowned for its excellent teaching and research in atmospheric, oceanic and climate science. Established in 1965, it is the only UK university which offers a full range of undergraduate and postgraduate courses in meteorology. Our research is world class, as demonstrated by the 2008 Research Assessment Exercise, which graded 75% of our research as world leading or internationally excellent, which makes us the highest-graded department focusing on the fundamental science of weather and climate. In 2005 Meteorology at Reading was awarded the Queen's Anniversary Prize for Higher and Further Education.

4. Factual Information:

1. *Background*

   Weather forecasting is a scientific endeavour. The Met Office therefore requires a strong science base in order to deliver its Public Weather Service Remit. The practical demands for increased skill in weather prediction and new applications of weather prediction require new scientific research. The UK atmospheric science community is world leading, as demonstrated for example by analysis of citations of scientific publications. This strength comes from the breadth of the community and the very close collaborations between the Met Office, the European Centre for Medium Range Weather Systems, the National Centre for Atmospheric Research and the University community.

2. *How effectively is the Met Office fulfilling its Public Weather Service remit?*

   A range of quantitative scores measures the skill of weather forecasts provided by the Met Office. The Met Office skill scores are consistently amongst the very best, if not the best, when compared with the other leading providers of weather forecasts from across the world.

3. *Is the Met Office's Science Strategy 2010-15 robust and achievable and how will the strategy help to deliver a better service?*

   The Met Office Science Strategy 2010-2015 is ambitious. It identifies challenges that are at the cutting edge of scientific research. Such an ambitious strategy is entirely appropriate for the Met

Office, with its history of excellence. As a specific example, the strategy emphasises the development of very high-resolution weather forecast system, known as the UKV model. This model is providing a step change in forecasts capability as it computes explicitly the occurrence of small-scale convective rainfall. At the University of Reading we are working very closely with the Met Office in the development of the science underpinning this forecast system, including formulation and testing of the model, the use of new observations to initialise the model, and methods of evaluating the skill of the model. This system will help deliver a better Public Weather Service by providing new capability in forecasting extreme rainfall. For example research at Reading has shown that the new system forecasts well the Boscastle Floods of 2004.

4. *What are the roles of the Met Office's Chief Scientific Adviser and its other senior scientists? How do they provide comprehensive and up-to-date scientific advice?*
   Julia Slingo was a Professor in the Department of Meteorology, University of Reading, for 15 years before taking up her current role as Met Office Chief Scientist. She continues to be a visiting Professor in the University. In this role, Professor Slingo visits the Department approximately once per month when she meets with research staff. She regularly attends and speaks at scientific meetings. In these ways Professor Slingo is a high profile member of the UK and international research community. This level of engagement with the research community contributes to her ability to provide robust and up to date scientific advice.

5. *How robust are the models used by the Met Office for weather forecasting, climate predictions, atmospheric dispersion and other activities?*
   The whole suite of models used by the Met Office is used within the University community, and particularly at the University of Reading, in research projects. This means that the models are subjected to a very high level of scrutiny, often in ways unanticipated by the development teams at the Met Office. This level of scrutiny substantially increases the robustness of the models. As a specific example, following the eruption of Eyjafjallajokull the UK research community quickly mobilised to measure ash concentrations and evaluate the performance of the modelling system. The results have now been reported in peer-reviewed scientific publications (e.g. Dacre et al 2011[1]).

6. *How effectively does the Met Office coordinate its activities with government departments, non-departmental public bodies, the UK research base and its international counterparts?*
   The Department of Meteorology has a long and fruitful tradition of scientific collaboration with Met Office. This collaboration has received renewed impetus in the last year with the launch of the Met Office Academic Partnership Scheme. Through this scheme the Met Office co-funds with the University a Professorial position at the University of Reading (the Joint Met Office Chair in Weather Systems). The University also fully funds a lectureship in Weather Systems to complement this post. The Joint Met Office Chair is responsible for coordinating research between the University and the Met Office. An early result of this collaboration was the

[1] Dacre, H. F., Grant, A. L. M., Hogan, R. J., Belcher, S. E., Thomson, D. J., Devenish, B., Marenco, F., Haywood, J. M., Ansmann, A., Mattis, I. 2011 Evaluating the structure and magnitude of the ash plume during the initial phase of the 2010 Eyjafjallajokull eruption using lidar observations and NAME simulations. J. Geophys. Res. 116 D00U03

Workshop on improving predictions for future European winters held on 31 January 2011 and an outline plan for delivering a new service.

Declaration of Interests

The University of Reading receives £50,000 per year as a contribution to funding the Joint Met Office Chair in Weather Systems. Approximately 25 Met Office research scientists are based at the Department of Meteorology, University of Reading.

Professor Stephen Belcher, Joint Met Office Chair
Professor in Meteorology
Department of Meteorology, University of Reading
October 2011

Written evidence submitted by Stephen Burt (MO 16)

REGARDING the role of the Met Office

SPECIFICS The Public Weather Service remit: "provide public access to historic weather information via our Library and Archive and climatological records."

CONTRIBUTED BY Stephen Burt. I am a freelance science writer specialising in meteorological and climatological topics, and a long-standing Fellow of the Royal Meteorological Society. Over the last 35 years or so I have authored over 100 relevant articles and papers, mostly with regard to UK weather.

***Note**: superscripts refer to references, which are collected at the end of this submission.*

1. Declaration of interests

1.1. The author does not derive any income from commercial value-added services relating to climatological data. He therefore has no interests to declare other than wishing to see access to the nation's weather records, collected and archived at public expense, be made much more readily available.

2. Situation

2.1. The Met Office remit is to "provide public access to historic weather information via our Library and Archive and climatological records", and yet only a tiny fraction of the available information is actually available to the public without incurring very large data charges.

2.2. The Met Office began digitising the UK's climatological and rainfall records in the early 1960s, and continues to do so today. The information − originating largely from a voluntary observing network, comprising today some 250 'climatological' sites and 3200 rainfall-only locations − is collected, quality-controlled and archived in computer format entirely at the public expense, yet almost none of these computerised archives are available to the public.

2.3. The information flow is now almost entirely one-way. Until the early 1990s, summary information was published in monthly and annual hardcopy publications (the *Monthly Weather Report*, first published in 1884, and *British Rainfall*, first published in 1860). In 1993, the Met Office terminated both publications. Since that date, only a minuscule fraction of the climatological and rainfall data in the Met Office archive has been published (despite online publishing being much easier than hardcopy). This is in marked contrast to other countries, which provide easy online public access to current and historical weather data at

no charge (Australia[1], New Zealand[2], Canada[3], The Netherlands[4] for example) or at a nominal charge only (USA[5]).

2.4. Many other countries are far ahead of the UK in publishing mapped weather information for the general public. While the Met Office last produced a Climatological Atlas in 1952, in the Netherlands an attractive coloured hardcopy Climatological Atlas[6] was published by Koninklijk Nederlands Meteorologisch Instituut (KNMI) in 2002 at a nominal €15 per copy. In Iberia a similar publication[7] was produced jointly by Agencia Estatal de Meteorología (State Meteorological Agency of Spain, Madrid) and Instituto de Meteorologia de Portugal (Portuguese Institute of Meteorology, Lisbon) in 2011.

3. Problem

3.1. The Met Office charges heavily for access to its computerised records – typically, hundreds of pounds for 50 years of standard daily temperature and rainfall data. Note that this is *not* 'added value' consultancy services, it is the *raw data* itself, which many other countries make available for free. It is likely that for most standard digitised climatological information, the cost of raising the invoice by the Met Office greatly exceeds the cost of accessing and supplying that information over a computer link.

3.2. A standard Met Office response to complaints regarding high charges is that 'the original paper records are available for transcription or photocopying within its Archives'. This is simply no longer the case with current information, most of which originates in digital format over computer links rather than via handwritten paper forms.

3.3. Met Office archived climatological information is available via other sources, such as the British Atmospheric Data Centre (BADC, part of NERC), but the terms of use preclude access to many users without prior permission being granted by ... the Met Office. The BADC interface is also notoriously difficult to navigate, perhaps deliberately so. It is self-evident that to be useful, any interface or portal needs to be user-friendly, versatile, comprehensive, and as simple as possible. Australia's Bureau of Meteorology climate site [1] is an excellent example.

3.4. The lack of published information also damages the relationship with the volunteer observers who have formed the backbone of the Met Office observing network for close on 150 years [8]. With little or no information now published, together with very little ongoing support from the Met Office, many co-operating weather observers rightly feel that there is little point in continuing to undertake the necessary manual daily observations. Partly as a result, the voluntary observing network has declined by 50% within a generation[9], causing lasting harm

to the nation's weather records. In 1975, there were 6220 rainfall observing sites in the United Kingdom; by 2010, the figure had been halved, to just 3214 [10].

3.5. This approach is in sharp contrast with other countries, which see the voluntary or co-operating observer networks as providing a long-standing, motivated, committed and low-cost resource. In today's tight public sector economy, it is difficult to understand why the Met Office largely ignores the potential of its voluntary observer network, in contrast to, for example, Ireland, Australia and the United States, where volunteers contribute typically 90% of the total observing network. (In the United States, there are today around 11,000 weather observing sites, most of which are run on a voluntary basis by individuals or communities.) However, these countries do make their observations available to the public.

4. Implication

4.1. Unlike time-sensitive output from operational forecast models, severely restricting access to current and historical climatological and rainfall data (and essential site and instrument information or 'metadata'), gathered and archived at public expense, confers no competitive benefit on the Met Office as its charging policies are themselves hugely uncompetitive. Instead, it stifles legitimate access to the data, whether for casual interest, private or academic research and commercial 'value-added' activities.

4.2. Is the network administration, data collection, quality-control, archiving and publication of climatological and rainfall records within the UK and overseas territories still a core part of the Met Office's public service remit?

4.2.1. It could be argued that the core function of the Met Office is a forecasting and warning function, and that the organisation has no need of data more than, say, 12 hours old to accomplish that task.

4.2.2. The collection and publication of collected marine climatological observations was, of course, the first function of the Meteorological Department of the Board of Trade, the predecessor of the Met Office, when it was set up under Admiral FitzRoy in 1854.

4.2.3. Of course, many other organisations, research bodies, government departments and individuals continue to require all manner of both recent and historical climatological information. Should this function remain within the Met Office? Or could it be best outsourced to a subcontractor, with a tighter remit and lower overheads?

4.3. With its high cost base (in operational aspects unrelated to climatological archiving) the Met Office cannot hope to compete in commercial value-added research services, which could be

provided by small specialist businesses were the data free or available on nominal subscription terms. In sharp contrast to other countries, this business sector does not exist to any significant extent in the UK. This is directly attributable to current Met Office charging and access policy on its archived climatological databases.

5. Need

5.1. The Met Office should be encouraged to make its entire digital climatological archives, and data catalogues, available online. Access should be free or at nominal charges, possibly by a subscription model for regular users.

5.2. Freeing up access would, once the infrastructure was in place, encourage the private sector to develop added-value climate services – including publications, consultancy, public awareness and a wider variety of specialist media spokespeople able to comment on significant weather events, climate change and other related topics.

5.3. There is no need to re-invent the wheel. Examples from other Commonwealth countries, particularly Australia's Bureau of Meteorology, provide an excellent template.

5.4. The nation's weather records lie currently largely unused on computer disks somewhere within the Met Office data centre. As a nation apparently obsessed with the weather, we should permit much freer access to weather information, and allow those records to be available to all.

6. REFERENCES

[1] Australia Bureau of Meteorology: http://www.bom.gov.au/climate/data/

[2] New Zealand national climate database: http://cliflo.niwa.co.nz/

[3] Canada: http://climate.weatheroffice.gc.ca/Welcome_e.html

[4] The Netherlands: http://www.knmi.nl/climatology/daily_data/selection.cgi

[5] USA: National Climate Data Center pages - http://www.ncdc.noaa.gov/climate-monitoring/#cirs

[6] Koninklijk Nederlands Meteorologisch Instituut - KNMI (2002) *Klimaatatlas van Nederland 1971-2000*. De Bilt, The Netherlands

[7] *Atlas Climático Ibérico: Temperatura del aire y precipitación 1971-2000* – softcopy available at http://www.aemet.es/documentos/es/divulgacion/publicaciones/Atlas-climatologico/Atlas.pdf

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