

THEO MURPHY INTERNATIONAL
SCIENTIFIC MEETING ON

**Handling uncertainty in weather and
climate prediction, with application to
health, agronomy, hydrology, energy
and economics**

**Thursday 4 – Friday 5 October 2012
The Royal Society at Chicheley Hall
Home of the Kavli Royal Society International Centre**

Organised by Professor Tim Palmer FRS

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- **Speaker biographies**
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Handling uncertainty in weather and climate prediction, with application to health, agronomy, hydrology, energy and economics
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Synopsis

This meeting follows on from the 2010 Anniversary Discussion Meeting on “Handling Uncertainty in Science” but with a focus on weather and climate prediction and downstream applications. How is uncertainty represented in weather and climate prediction? How reliable are representations of uncertainty? How can decision makers in weather and climate sensitive sectors make useful decisions in the light of uncertain input? Are current ensemble weather and climate prediction systems useful for decision making across a variety of application sectors? How should probability forecasts be presented to the public?

Thursday 4 October 2012

09.00 - Welcome by the Royal Society

Session 1

Chair: Professor Judy Curry, Georgia Tech, Atlanta, USA

09.05 Uncertainty in weather and climate prediction: some introductory remarks

Professor Tim Palmer FRS, University of Oxford, UK

Whilst deterministic forecasts of weather and climate are manifestly unreliable, ensemble forecasts which properly take account of prediction uncertainties provide statistically reliable probabilistic predictions on which users can base their weather and climate sensitive decisions. How close are we to being able to produce statistically reliable ensemble forecasts? For medium-range weather prediction we are really very close. As such, the time has come where the public needs to be informed about our capabilities in probabilistic prediction. But how? On seasonal timescales, reliability is poorer - most importantly, I believe, we do not yet know how to estimate model uncertainty adequately. What are the implications for the climate services programme of this partial state of knowledge about uncertainty?

09.30 Discussion

09.40 Ensemble prediction of weather and its impact

Mr Ken Mylne, Met Office, UK

Ensemble prediction is now the standard approach to handling uncertainty in weather forecasting. Originally developed to address rapid error growth in 3-10 day synoptic scale forecasts, the technique is now applied on all time ranges. The recent advent of models capable of resolving convective storms offers prediction of much greater local detail of high-impact weather, but also error growth timescales of hours rather than days, and hence the need for ensembles at the shortest time ranges. The Met Office demonstrated a new convective-scale ensemble during the London 2012 Olympic Games, which has already demonstrated a capability to provide greatly enhanced confidence in some extreme events such as the localised flooding in Wales in June.

In order to prioritise their response to predicted severe weather, decision-makers need to understand the expected impact. UK severe weather warnings were recently upgraded to a risk-based system taking account of both likelihood and impact, with ensemble forecasts used to provide first-guess warnings. The Met Office and BBC are also experimenting with ways to communicate uncertainty effectively to decision-makers and the public. Ensemble forecasts are increasingly propagated through impact models to understand the uncertainty in impact. By combining these forecasts with geo-spatial information on vulnerability, we are able to offer increasingly effective decision-support tools to aid effective management of environmental risk.

10.05 Discussion

10.15 Sustainability through hazard anticipation and mitigation

Professor Peter Webster, Georgia Tech, Atlanta, USA and

Dr Jeremy Hess, Emory University Department of Emergency Medicine, USA

Over the planet, hazards such as floods, storms, droughts and heat waves cause havoc, death, social disruption and starvation. In terms of impacts, the less-developed world is most affected where anticipation of a hazard is minimal due to lack of warning and societal resilience is blunted by lack of substantial resources. All too often, coping with successive hazards depletes household capital and leads to irreversible intergenerational poverty. But these adverse affects need not necessarily follow. Extended probabilistic forecasting of floods and tropical cyclones can provide advanced warning of hazard risk extending well beyond the time scale necessary to evacuate the slowest groups of society. We will provide examples of storm and flood forecasting in Bangladesh used to mitigate the impacts of environmental hazards and also show that flood forecast developed for Pakistan in 2010, 2011 and 2012 may have allowed catastrophe to be avoided.

In addition, these predictable environmental hazards have a range of health impacts that are both directly and indirectly mediated. Direct impacts range from injuries including drowning in floods, trauma from flying debris, and heat illness. Indirect impacts include exacerbations of chronic diseases, increases in diarrheal and other infectious diseases, malnutrition, and health impacts secondary to loss of wealth and livelihood. Worldwide, indirect impacts account for a majority of the overall disease burden. Many of these impacts are preventable with appropriate interventions, though interventions requiring substantial infrastructure investment can be difficult to mount in low resource areas. To the extent that hazards can be predicted and vulnerable populations can be effectively warned, however, preventive actions can reduce impacts both directly, by limiting exposure, and indirectly, by limiting damage to infrastructure and productive capital, at a relatively low cost.

As the nature of environmental hazards shifts under the influence of global change, more people and infrastructure are likely to be in harm's way. However, we feel that a society that learns to mitigate the impacts of hazards in the current climate will be most adept at dealing with perhaps more intense hazards in the future. Over time, reducing losses from hazard exposure can result in more rapid economic development, itself one of the most important drivers of health status. Systems dynamics methods can be used to illustrate and study these associations between shifting hazard landscapes, probabilistic early warning systems, preventive actions, and accumulation of household and community wealth.

10.40 Discussion

10.50 COFFEE

11.20 Communicating forecast uncertainty

Mr Arjunapermal Subbiah, RIMES:Regional Integrated Multi-Hazard Early Warning System, Thailand

Advances in weather prediction have provided the public with a suite of weather and climate information products of up to 3 days, 10 days, 25 days, and 3-6 months or more into the future. Forecast reliability, however, decreases with longer lead times. With the tremendous application potential of long-lead forecasts in planning and decision-making, management of forecast uncertainties is crucial. This requires engagement with users, who are diverse, with differing perceptions, experiences, interests, and priorities, and tailoring accordingly the communication of forecast information and their inherent uncertainties. The Regional Integrated Multi-hazard Early warning System (RIMES) evolved and put into practice two institutional instruments Monsoon Fora and Climate Field Schools to communicate forecast uncertainties.

Monsoon Fora and Climate Field Schools provide platforms for forecast provider dialogues with institutional and end users, where user needs are presented, forecast product generation and inherent uncertainties are communicated, forecast usability feedback is received, forecast application constraints are discussed, and recommendations and follow-up actions to issues identified are elaborated. User training in forecast interpretation and translation into potential impacts and responses, and demonstrations of long-lead forecast application within a risk management framework build user confidence in probabilistic forecast information.

11.45 Discussion

11.55 Probabilistic prediction without probabilities

Professor Leonard Smith, London School of Economics, UK

The confidence with which quantitative representations of uncertainty can be employed in decision making differs in the cases of (i) repeated, arguably "identical" trials (rolling a die), (ii) repeated, arguably similar trials (next Saturday's high temperature) and (iii) effectively unique events (the high temperature in Oxford during August 2084). It is argued that model-based probability distributions are fundamentally incomplete representations of uncertainty; two alternatives for the quantification and communication of decision-relevant probabilistic forecasts are presented.

P D Thompson argued for quantifying the growth of forecast "error" given the current state of the atmosphere thirty years before H Tennekes famously noted that no forecast was complete without an estimate of forecast error. I J Good came closer to an explicit call for probability forecasts in 1952, suggesting that Met Office personnel receive a bonus based on their improvement of a proper, local probability score. With no suggestion of returning to definitive forecasts of the future, the common notion of providing model-based probably forecasts, to be used as probabilities in decision making, is challenged. More generally, the utility of stand-alone probability forecasts is questioned for cases where the decision maker does not have complete and absolute trust in the algorithm by which the probability forecast is constructed. This suggests more than a probability is required to complete the forecast.

It is argued that no model-based probability forecast is complete without an explicit estimate of its likely irrelevance regarding the future. The core issue here is that, inasmuch as one accepts that all models are but models, the core probabilities that are estimated relate only to the probability of the model runs, not events in the world. How might known model inadequacies be quantified and communicated? Two approaches are considered. The first aims to quantify second-order uncertainty in model-based probabilities directly, by elicitation of the probability of a "big surprise". The second is to replace the notion of probability-based fair odds with that of "sustainable odds". Sustainable odds aim for a rational expectation of breaking even (making neither a profit nor a loss), while accepting that the model(s) upon which probability forecasts are based are imperfect. It is argued that if fair odds correspond to probability forecasts then they are not sustainable in this case. Arguably, this result is neither surprising nor novel, nevertheless it impacts how probabilistic forecasts are communicated, evaluated and used. It distinguishes clearly the aims and nature of quantitative decision support situations where verification data are available, as in games and weather forecasting, from those where it is not, as in climate forecasting.

12.20 Discussion

12.30 LUNCH

Session 2

Chair: Professor Peter Webster, Georgia Tech, Atlanta, USA

13.30 Weather prediction and hydrology

Dr Florian Pappenberger, ECMWF, UK

There are significant differences between meteorological and hydrological forecasting. Hydrological forecasting relies mainly on predictants and there is little access to variable states for data assimilation thus at present data assimilation is of little value beyond the natural time scale of the river catchment response. However, forecasts within that timescale do not need forecast inputs; however these can be measured inputs and usually they ignore any mass balance constraints. Medium-range hydrological forecasting (~3-15 days) requires weather forecasts as well as and hydrological monitoring as input, as the required lead time is in excess of the natural lag within a catchment.

The uncertainty in this forecasting chain is widely recognised in Hydrology: hence the advent of Hydrological Ensemble Prediction Systems (HEPS). Such uncertainty comes from various sources and procedures within the forecasting process and can be difficult to accurately quantify. The uncertainty from the weather forecast is often considered to be the most influential and hence ensemble weather forecasts are now routinely used in many forecasting situations, such as in the European Flood Awareness System. However, hydrological model and parameter uncertainty and observational uncertainty is also essential to understand, and this is not always straightforward to apply in a forecasting system. This is true for small scale river flow prediction but becomes increasingly challenging for global scale hydrological prediction coupled to atmospheric models.

Because of this uncertainty, the value of such medium range hydrological forecasts lies mainly in alerts rather than warnings or concrete decisions as ensembles do not always span the observed values (low reliability). This maybe improved with higher resolution models and at convective scale local surface hydrology will become more important and we may see a convergence of hydrological forecasting models and current land surface schemes. Here we look at hydrological forecasting and uncertainty over a range of timescales.

13.55 Discussion

14.05 Weathering the drought: Building resilience in the face of uncertainty

Dr Rosalind Cornforth, University of Reading, UK

The West African Sahel is currently suffering food shortages with 19 million people at risk. In the face of ongoing and future crises in the region, resilience remains a contested concept. People are challenged with adapting in the face of a global sustainability problem that will lead to recurring and potentially irreversible crises. Given this challenge and that short-term weather and seasonal climate forecasting still have limited skill for West Africa, near real-time monitoring and improved communication channels can make a difference to real peoples' lives by helping them to prepare for future uncertain events. Here we present practical innovations for tolerating uncertainty through the course of a monsoon season. We focus especially on the Rainwatch project applied to the monitoring of the 2011 West African rainy season, and the resulting severe drought-induced humanitarian impacts continuing in 2012. We identify three defining features for managing for climate resilience in the face of uncertainty: 1. Effective monitoring and communication of weather and climate; 2. Committed individuals actively engaging in building stakeholder relations; 3. Sufficient time frames to

develop an effective system. At a bare minimum, institutions must establish practical and tangible innovations to anticipate impending crises. This includes identifying rainfall deficits through long-term monitoring and timely communication of user-relevant information, access to relevant and reliable forecasts, and the ability of stakeholders to act on that information.

14.30 Discussion

14.40 Climate and food: adapting in the face of uncertainty

Professor Andy Challinor, University of Leeds, UK

Quantification of uncertainty is now an important part of agricultural impacts assessments. Approaches have evolved over time, with ensemble climate modelling having a particular influence on the methods used. Current approaches seek either to quantify or reduce uncertainty. After a brief review of methods developed over the last few decades, examples of both of these types of approaches are given. Key elements include assessment of sources of uncertainty and their relative contribution to the total; and efforts to understand which sources of climate and weather uncertainty are important for agricultural impacts. The final part of the talk presents a framework for assessing uncertainty when developing options for agriculture to adapt to climate change. In particular, we ask how climate information can be used to inform adjustment and transformation of agricultural systems.

15.05 Discussion

15.15 TEA

15.45 The value of probabilistic weather forecasts to the commodity markets

Dr Warwick Norton, PCE Investors, UK

Weather influences supply and demand in many tradable commodities. This talk gives some examples as how weather forecasts are used in pricing and managing risk in energy and agriculture. Weather has become increasingly important in the generation of electricity because of the massive investment (of some countries) in renewable energy - solar and wind energy combined with the more traditional hydropower. This creates significant variations in price which can be hedged in the financial markets. Examples of nonlinear sensitivity in price to changes in weather illustrate why a probabilistic view of weather forecasts is required.

This view extends to understanding the large-scale flow pattern where weather regimes are a useful tool. However even then, jumps in probabilities can occur in successive ensemble forecasts which create difficulties for decision makers.

The WMO Global Framework for Climate Services will make more weather and climate information (including seasonal forecasts) available. It is discussed how this might allow agricultural markets and end users to make better decisions.

16.10 Discussion

16.20 Weather forecasts and macroeconomic forecasts: a comparative study

Dr Reason Machete, University of Reading, UK

The weather forecasting community has a long history of issuing ensemble forecasts of weather variables such as temperature, pressure and rainfall. The ensemble forecasts are obtained by integrating a complex nonlinear model with different initial conditions or parameters. The raw ensemble forecasts are not decision relevant; they may manifest defects such as bias and under-dispersion. Because of these defects, the forecasts will not be reliable. The weather community has developed tools and techniques for diagnosing and mitigating these shortcomings.

On the other hand we have the economics community who issue density forecasts, sometimes using complex nonlinear models as is done at the Bank of England. The process for producing probabilistic forecasts of macroeconomic variables is often not as transparent as in weather forecasting, but the model may be admittedly imperfect. Are the issued forecasts decision relevant?

This study compares and contrasts defects of probabilistic forecasts of weather variables with those of macroeconomic variables. Contending that calibration is a mirage, possible ways of mitigating forecasts limitations are explored. We consider ensemble forecasts of sea-surface temperature, London temperature and some macroeconomic forecasts issued by the Bank of England and the Survey of Professional Forecasters in the US.

16.45 Discussion

16.55 CLOSE

18.15 Pre-dinner drinks

18.30 DINNER

Friday 5 October 2012

Session 3

Chair: Professor Paul Hardaker, Institute of Physics, and University of Reading, UK

09.00 Using or refusing uncertainty information in the energy sector

Dr Renate Hagedorn, Deutscher Wetterdienst, Germany

The energy sector is an area with pronounced sensitivity to unexpected weather events. The main challenge for Transmission System Operators (TSOs) is to ensure the stability of the grid by continuously balancing production and demand of electricity. In particular the increasing proportion of renewable energy sources in the energy mix poses a great challenge. Due to their strong dependency on weather they are fluctuating in time, and it is of great importance to anticipate any possible extreme event or rapid change. Therefore, many users in this sector are actively asking for probabilistic forecasts, i.e. information on different possible future scenarios. However, it is not yet always clear how the decision-making is - or should be - based on this probabilistic information. That is, although the research and development divisions of the TSOs request this kind of information, in reality the operation managers are not used to integrate it into their day-to-day decision-making. This dichotomy between theoretical advantages and practical hurdles on the way of establishing the use of uncertainty information will be discussed, and possible strategies to overcome this situation will be outlined.

09.25 Discussion

09.35 Climate forecasting and health

Dr Andy Morse, University of Liverpool, UK

Climate model data, climate model data every where and nor any drop to benefit our health*.

Much as Coleridge's Ancient Mariner was surrounded by sea water, global models running over a variety of lead times are producing data on a continuous basis. These data sets could have utility to many user communities, including health, only if those communities, or their agents, could access, process, understand the limitations and uncertainty of those modelling data sets. Further the user communities need to develop their own modelling systems and methodologies to use it in early warning, planning and development activities.

The above sentiment was the state of play in the late 1990s before a successful series of projects, through the EC Framework Programmes and nationally funded projects, started to bridge across the gap between producers (of data) and the users (of data) by creating a new area of research and development; very much at the interface between climate science and society. Much progress has been made on all aspects of data use and the production of tailored products for health user communities but beyond a small number of examples it is still not operational for health impacts, especially for infectious diseases. The community developing such systems is still small. This paper will briefly highlight the milestones in the development of the use of climate model data for running dynamic infectious disease models. Dynamic impacts models that make use, in a non-linear transformation, the frequency of meteorological events as well as their average magnitude.

This paper will show the use of disease models, particularly the Liverpool Malaria Model (LMM), driven by a range of climate modelling systems from seasonal ensemble prediction systems (EPS) to

ensembles of climate projection models; using LMM as the seamless slider, for users, between the different driving climate model systems. Discussion of the representation of uncertainty in the LMM outputs will be highlighted and how this information in turn is conveyed to users and decision makers will be presented. The improvement of seasonal forecast skill across generations of EPS and the discussion of the utility from a health user's perspective will be highlighted. A recent development has been the addressing of impact model uncertainty through the use of multiple malaria models. This allows the question to be addressed to see if the uncertainty in the driving climate models is the principle source of the total uncertainty or does this overall uncertainty, for decision makers, come predominately from the structure and parameter settings of the impacts models themselves.

Finally the paper will highlight the current research priorities needed to improve the end-to-end delivery of relevant climate information to health user communities.

Whilst you were reading this abstract, approximately two people will have died from malaria; most of those deaths occurring in children under five years of age and living in sub-Saharan Africa.

*Acknowledgement to Samuel Taylor Coleridge, *The Rime of the Ancient Mariner*, 1798.

10.00 Discussion

10.10 Climate models: fit for what purpose?

Professor Judy Curry, Georgia Tech, Atlanta, USA

Climate models are being used to support emissions reduction policies and as the basis for projection of future regional climate variation for use in model-based decision support systems. Largely motivated by these applications, priorities for climate model development are focused on increasing resolution and adding complexity in the context of fully interactive earth system models.

Arguments are presented that there is misguided confidence and "comfort" with the current climate models and projected developments that are not consonant with understanding and best practices from other fields. The fitness for purpose of climate models is examined in the context of different decision making applications for which climate models are being used. The decision analytic framework of reducing scientific uncertainty in support of optimal decision making strategies regarding CO₂ mitigation has arguably resulted in unwarranted high confidence in future projections and relative neglect of natural climate variability and the possibility of black swans and dragon kings.

The climate change problem is characterized by high levels of uncertainty, and modeling and subjective judgments substitute extensively for estimates based upon experience with actual events and outcomes. Hence a decision analytic framework of 'decision making under deep uncertainty' is a much better match to the climate problem, where understanding uncertainty and areas of ignorance is critical information for the decision making process. Potential applications of climate models under different decision analytic frameworks are described, motivating consideration of alternative paths for climate model development.

10.35 Discussion

10.45 COFFEE

11.15 Climate adaptation: learning to live with uncertainty

Professor Suraje Dessai, University of Leeds, UK

Societies, organisations and individuals have been adapting to changing conditions for centuries but the advent of climate change brings new challenges. One peculiar challenge is that we only have partial knowledge of what the future may look like. The presence of deep/severe uncertainty about the future – of climate, climate impacts and society – makes anticipatory adaptation difficult. Given these circumstances, this talk will explore approaches to handling uncertainty – robust decision making and information gap decision theory – that maximise the immunity of adaptation strategies to large ranges of uncertainty. I will illustrate these approaches using case studies of long-term water resources planning.

11.40 Discussion

11.50 Climate science and the humanitarian sector

Professor Dominic Kniveton, University of Sussex, UK

The most tangible benefits for society of progress in climate science are often thought of as the ability to forecast weather and climate from daily, through seasonal to decadal timescales. Potential users of this information are the institutions and individuals that comprise the international humanitarian system. Criticised for its reactive mode of operation, recent reviews of the humanitarian system have called for a reorientation towards an anticipatory approach and one that incorporates the benefits of science. Potentially seasonal forecasts could provide some of the inputs for some types of anticipatory decision-making by agents of the humanitarian system. However despite their existence for over 15 years in regions such as Africa, which are regularly blighted by climate related humanitarian crises, uptake of seasonal forecasts has been, to date, largely restricted. In this paper we outline possible reasons for this limited uptake and sketch out a framework and process by which it may be addressed. In particular we review some of the cognitive biases in decision making using uncertain climate information, the difficulty that some decision makers find interpreting probabilistic forecast information, and the different aspects of the political, institutional, and cultural contexts that affect humanitarian users' flexibility to make use of climate forecasts. Finally we outline some of the research questions that may be pursued to help benefit this nexus of climate science and the humanitarian sector.

12.15 Discussion

12.25 LUNCH

Session 4

Chair: Professor Leonard Smith, London School of Economics, UK

13.25 Uncertainty and understanding: Some approaches for making climate science useful and enabling direct dialogue between the providers and users of climate science

Emma Visman, Humanitarian Futures Programme, Kings College London, UK

Since 2009 the Humanitarian Futures Programme, King's College London, has been supporting an exchange between a group of climate scientists, meteorologists and humanitarian organisations. The exchange includes two demonstration studies – one in Senegal and one in Kenya – as well as dialogue activities within a Natural Environment Research Council Knowledge Exchange Fellowship.

Learning from the exchange has made clear that, to effectively support those most at risk, climate information needs to be contextualised within the multi-hazard environments in which these communities live. The process of making climate science useful requires the development of dialogue approaches which challenge existing assumptions on the part of both the providers and users of science about how information can best support different levels of decision making and demonstrate value in the shorter-term. This process encompasses (1) strengthening levels of scientific literacy within communities at risk, as well as amongst the wide range of humanitarian and development agencies which seek to support them; (2) enabling scientists to develop understanding of the contexts in which scientific information is to be applied; and (3) creating approaches which support direct, two-way dialogue and identifying resources to enable more systematic, sustained provider-user frameworks for engagement.

13.50 Discussion

14.00 An '80% chance of confusion', or can the public make use of probabilistic weather forecasts

Liz Stephens, University of Bristol, UK

Ensemble techniques allow for uncertainties in weather forecasts to be quantified, but for many reasons there is often a reluctance to communicate this information to the public. In particular, there is concern that forecast users might not be able to understand this complex ensemble information. The UK Met Office aimed to address this concern by employing an online weather game as a mass participation experiment to test different ways of presenting ensemble weather forecasts online. The game used a hypothetical 'ice-cream seller' scenario to test the ability of participants to understand uncertainty information presented in different formats, with data also collected on participant age, gender and educational attainment. This allowed for an identification of the optimum methods of communicating uncertainty in rainfall and temperature forecasts, as well as exploring any potential demographic influences on understanding. This presentation discusses the results of the weather game, as well as talking more broadly about the challenges of communicating ensemble forecasts to end-users.

14.25 Discussion

14.35 Weather forecasting at the BBC

Liz Howell, Head of BBC Weather

The BBC is one of the largest news organisations in the world and its weather content on TV, online and radio is a core public service delivered by its news division. BBC audiences have a high interest in weather - they expect accuracy, timeliness and relevance in forecasting to help them live their lives and see the context within which others are living. So what are the audience expectations and challenges in weather broadcasting, and how should we develop explanations of the science and further understanding of probabilities and confidence in forecasting?

15.00 Discussion

15.10 TEA

15.40 Sense about Science: making sense of uncertainty

Professor Paul Hardaker, Chief Executive of the Institute of Physics, and University of Reading, UK and Tracey Brown, Sense About Science, UK

The challenges facing the public and policy makers in dealing with uncertainty in science are not new. Both Aristotle and Plato struggled with this in their work on 'socialising science'. Some two and a half thousand years later the French philosopher Denis Diderot wrote in a discourse on scepticism that it may not be possible to know anything with absolute certainty and that the process of questioning is the first step on the road to truth. This long association between uncertainty and scepticism has long troubled the communication of science.

Scientific uncertainty features most prominently at the boundaries of our scientific knowledge and in the very areas of scientific research that have the biggest implications for society: could the Arctic become ice-free in the summer by 2080? Will a new cancer drug be worth its side effects? Is this strain of 'flu going to be a dangerous epidemic?

Uncertainty is normal currency in research. Science reports findings in terms of how confident we can be that they really tell us what is going on. Scientists are interested in things precisely because they are uncertain and our understanding of uncertainty guides research efforts towards areas where new insight will have the greatest impact.

In public discussion, uncertainty about the frontiers of research, whether it be in climate science, drug development or prediction of natural hazards, is presented as worrying. That is not surprising. We want safety, policies that will work and public expenditure that is both affordable and demonstrates its usefulness. We do not welcome the idea that anything could turn out to be true.

But could it? In emotive political areas, uncertainty has been used to suggest that evidence cannot be relied upon, and many implausible products and theories are promoted by emphasising the uncertainty of mainstream knowledge. These are, though, distortions of the working knowledge we do have and they reveal a gap between what scientific uncertainty means and how it is portrayed.

To make better judgements in policy and society at large, we need to close this gap. This means widening awareness that:

- When we talk about uncertainty we do not always mean the same thing. What does a given level of uncertainty mean in a particular context? There is an uncertainty in our understanding of the laws of physics, for example we know that Newton's Laws are an approximation, and yet that does not mean that these laws are of no use to us. We can make predictions of the future that are based on an uncertain representation of physical laws and bounded by a range of outcomes, and express these in terms of probabilities. We can assess our knowledge and quantify the uncertainty, for example with error bars. These are all different realisations of uncertainty, which sometimes confuses public debate.
- Uncertainty does not mean that anything goes, or that it is impossible to be certain of anything surrounding the issue under discussion. Rather, uncertainty shows that an investigation of the subject has been taken seriously. Scientists should be able to talk about uncertainty without suggesting that every topic in a whole discipline is open to interpretation. We need to be clear, too, that uncertainty in one account of phenomena does not mean that we should necessarily have greater confidence in an alternative account.
- As time goes on, and more research is done, the level of uncertainty may change. But the scientific method is not completely intuitive nor is it linear. Often we can be more certain about long-term trends than, for example, next week's weather.
- There is much research dedicated to dealing with data and modelling uncertainty. Data can be 'noisy' or 'missing' and models are designed with assumptions. These impose limitations on what we can conclude, which do not mean the data or models are invalid, but that researchers and users have to be clear about those limitations.

Only a limited number of our science teachers in school have a discipline-specific training and we spend little time in our curriculum on topics like uncertainty. A recent survey showed that some 80% of the adult population still access science through TV and the media, and yet often poor reporting of the evidence and the uncertainty inherent within it goes unchallenged. The internet is now a significant source of information on risk, particularly in environmental and health issues, but tends to reinforce stereotypes and polarise opinion about whether 'the scientists can't make up their minds'.

Street interviews with the public have shown that they want to hear more from scientists as a trusted source of information and they want to hear more about how to interpret what the science is telling us. Uncertainty is a vital part of this conversation but it needs attention in how we communicate and it needs popular ownership, if we want public discussion to move forward.

16.05 Discussion

16.15 Final Discussion

16.50 CLOSE

18.30 DINNER for those resident at Chicheley Hall on Friday 5 October

Biographies

Tracey Brown, Sense About Science, UK

Tracey has been the Director of Sense About Science, a charity that equips people to make sense of science and evidence, since shortly after it was established in 2002. Tracey has a background in social research, and previously spent four years working on a European Commission programme to establish social research and teaching in the former Soviet Union, and a year setting up a commercially based risk analysis centre. Tracey has written about scientific evidence, policy and the public, for *The Times*, the *Guardian*, and a range of periodicals, including a regular column in *People & Science* and contributed to books on the subject, most recently 'Successful Science Communication'. In 2010 *The Times* named Tracey as one of the ten most influential figures in science policy in Britain. She is a trustee of Centre of the Cell and MATTER and a commissioner on the UK Drugs Policy Commission. She sits on the Outreach Committee of the Royal College of Pathologists and in 2009 was made a Friend of the College. In 2011 Tracey joined the board of the UCL Jill Dando Institute of Security and Crime Science and the Advisory Board of the journal *Agriculture and Food Security*.

Professor Andy Challinor, University of Leeds, UK

Andy Challinor is a Professor of Climate Impacts at the University of Leeds. His research focuses principally on using climate modelling and process studies to understand food production and food security, treatments of uncertainty and managing risk, and climate-resilient pathways and adaptation. Andy is the PI of the NERC EQUIP consortium and Theme Leader for 'Adaptation pathways under progressive climate change' – one of four themes of international programme on Climate Change, Agriculture and Food Security (CCAFS). He is also Research Director for the University of Leeds Africa College Partnership and Lead Author on the 'Food Production Systems and Food Security' chapter of the forthcoming Fifth Assessment report of the IPCC.

Dr Rosalind Cornforth, University of Reading, UK

Dr Cornforth has a PhD from the University of Reading and joined Reading's renowned Department of Meteorology in 2005. She is Director of AfClix (the African Climate Exchange) through a NERC Knowledge Exchange Fellowship, and is a Research Scientist in the National Centre for Atmospheric Science (NCAS-Climate). Her research is focussed on improving our understanding of the fundamental dynamics and predictability of rain-bearing African weather systems and she has authored several papers on the fundamental dynamics of the African monsoon. As Director of AfClix, Rosalind has responsibility for leading ground-based initiatives in Sub-Saharan Africa to help ensure that all climate-related policy decisions towards improving food security can access the best-available scientific information. Together with colleagues from other disciplines and other sectors (eg. NGO and government policy-makers), she has co-authored high profile peer-reviewed perspectives on building practical resilience in developing countries. She has worked as an Editor on the Royal Society's Special Issue in Philosophical Transactions A on Water, Life and Civilisation and is currently on the Editorial Committee and a chapter lead author for the first Forecaster's Handbook for West Africa which will document forecasting methodologies and 'state of the art' scientific understanding. Rosalind is also an active participant of several groups concerned with improving predictability of high impact weather (eg. African-led THORPEX Africa WG; DFID-Climate Science Research Partnership).

Professor Judy Curry, Georgia Tech, Atlanta, USA

Dr Judith Curry is Professor and Chair of the School of Earth and Atmospheric Sciences at the Georgia Institute of Technology and President of Climate Forecast Applications Network (CFAN). Dr Curry's research interests span a variety of topics in climate research, including issues at the climate science policy interface. Dr Curry is the proprietor of the blog Climate Etc. <http://judithcurry.com>. Dr Curry is a fellow of the American

Meteorological Society, the American Geophysical Union, and the American Association for the Advancement of Science.

Professor Suraje Dessai, University of Leeds, UK

Suraje Dessai is Professor in Climate Change Adaptation at the Sustainability Research Institute, School of Earth and Environment, University of Leeds. He is the recipient of a European Research Council Starting Grant on "advancing knowledge systems to Inform Climate Adaptation Decisions" (ICAD; 2012-2016). Suraje is also currently involved in two large multi-institution projects: Water System Resilience (ARCC-Water) and End-to-end Quantification of Uncertainty for Impacts Prediction (EQUIP). He is an Associate at the UK's Centre for Climate Change Economics and Policy (CCCEP) and a visiting scientist at the Climate Change Impacts, Adaptation and Mitigation Unit of the University of Lisbon. Suraje has published 37 peer-reviewed papers in journals such as *Science* and *Global Environmental Change*, 7 book chapters and edited two journal special issue. He is currently a Lead Author on the chapter "Foundations for Decision-making" for the Intergovernmental Panel on Climate Change (IPCC) Working Group 2 (Impacts, Adaptation and Vulnerability) Fifth Assessment Report and also serves on the IPCC's Task Group on Data and Scenario Support for Impact and Climate Analysis. Suraje's current research and teaching focuses on the management of climate change uncertainties, perception of climate risks and the science-policy interface in climate change impacts, adaptation and vulnerability.

Dr Renate Hagedorn, Deutscher Wetterdienst, Germany

Dr Renate Hagedorn is part of the scientific and operational management division in the business area "Weather Forecasting Services" at Deutscher Wetterdienst (DWD). Dr Hagedorn gained her PhD at the Institute for Marine Sciences in Kiel, Germany, where she developed a coupled atmosphere ocean model for the Baltic Sea catchment area. Subsequently she joined the European Centre for Medium-Range Weather Forecasts (ECMWF) in Reading, UK. There she worked on diagnostics and applications related to ECMWF's Ensemble Prediction Systems, both on seasonal and medium-range time-scales. In 2006 she was awarded, together with colleagues from the DEMETER project, the Norbert Gerbier-Mumm International Award by the World Meteorological Organization. More recently Dr Hagedorn moved back to Germany to join the German National Weather Service DWD, where she is responsible for developing and coordinating various projects in the area of renewable energy applications.

Professor Paul Hardaker, Chief Executive of the Institute of Physics, and University of Reading, UK

Paul is currently Chief Executive of the Institute of Physics. He is also the General Secretary of the International Union of Pure and Applied Physics, and a visiting professor in the School of Mathematical and Physical Sciences at the University of Reading. Paul is Chairman of Sense about Science, a charity that campaigns for better reporting of science in the media, and is a Board member of the Science Council, a federal body representing the profession of science in the UK.

Paul is a mathematician by background whose early research work focused on modelling and instrument studies in radio propagation, working with organisations such as British Telecom, the European Space Agency and the Rutherford-Appleton Labs. He later moved to the Met Office where he spent 14 years in a variety of roles including heading up an international consultancy on hydrometeorology, and the Remote Sensing and Observations Branches. He then became Programme Director for the Met Office's Development Programmes and latterly the Met Office's Chief Advisor to Government, providing support to the Government in areas such as climate change policy and the civil contingency programme.

Following his time at the Met Office, and before taking over at the Institute of Physics, Paul was the Chief Executive of the Royal Meteorological Society (the Learned and Professional Society for weather and climate). Whilst in that role he was a member of the Science Steering Group for the UK's Joint Weather and Climate Research Programme and the Advisory Board for e-Research South. He was also a member of the Standards Quality Council for the qualifications awarding body PAAWQSET.

Paul has led the UK delegation to several UN and EU technical committees on meteorology, he has been a member of the Physics Advisor Panel at the University of Wales, one of the Government's Science and Society Champions, Chairman of one of the UK's national e-Science projects, and the founding editor of the international journal Atmospheric Science Letters (ASL). Paul has also been the Interim General Manager for EcoConnect, a joint-venture between the UK and New Zealand Governments to provide environmental services across the globe, and for 3 years, a Non-Executive Director and Chief Scientist of a City company working in risk management. He was the Chairman of the UK Research Council's programme on the Flood Risk from Extreme Events (FREE) and for eleven years, until 2009, held a visiting professorship at the University of Salford. For five years Paul was also a Non-Executive Director and latterly Deputy Chair of the Board of NHS Berkshire West, one of the UK's regional Primary Care Trusts.

Dr Jeremy Hess, Emory University Department of Emergency Medicine

Dr Hess is a board-certified emergency medicine physician also trained in global environmental health. He currently divides his efforts between the clinical practice of emergency medicine and environmental public health research and practice focused on the health effects of climate change. He is on the faculty of the Emory University Department of Emergency Medicine and has a joint appointment in the Department of Environmental Health in Emory's School of Public Health. He also serves as a Senior Medical Advisor with the Climate and Health Program in the Division of Environmental Hazards and Health Effects at the CDC's National Center for Environmental Health.

For his undergraduate studies Dr Hess attended Deep Springs College and Brown University, from which he graduated with Honors. He went on to found a youth AIDS prevention program in Thailand as an Echoing Green Fellow and was the inaugural Director of the AmeriCorps Community HealthCorps program in Providence, RI. He pursued medical and public health training at Emory University, where he was awarded a full-tuition Woodruff Fellowship in the School of Medicine, the Sellers Merit Scholarship to the Emory School of Public Health, the Emory University Humanitarian Award, and the Gangarosa Scholarship for Outstanding Achievement in International Health. Dr Hess did his emergency medicine residency at Emory, as well, where he received several awards including the Award for Academic Excellence.

Dr Hess's recent public health work has focused on public health preparedness for extreme weather events. He has served on several advisory committees for the US government focused on climate change and health and as a Lead Author on the Intergovernmental Panel on Climate Change's special report on *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX)*. Along with others in the CDC's climate change program, Dr Hess recently received the Presidential GreenGov Award for the interagency report "A Human Health Perspective on Climate Change," for which he was a lead author. He is also a Lead Author on the upcoming National Climate Assessment and the author of over 30 peer-reviewed publications and assessments.

Dr Hess is a Fellow of the American College of Emergency Physicians and lives in Atlanta with his wife and two young children.

Liz Howell, Head of BBC Weather, UK

Liz graduated with a BSc (hons) degree in Human and Environmental Biology following which she began her career in journalism at the Nottingham Evening Post as a news reporter, feature writer and columnist. After moving to the BBC, Liz worked on regional TV news programmes in the Midlands, latterly as Output Editor managing all TV news, current affairs and TV documentary programming in the region. During this time Liz ran a major relocation project and led the introduction of revolutionary server based broadcasting technology for all radio and TV operations in the region.

In 2001 Liz took charge of the BBC's News Interactive service for England. Working from Pebble Mill, she oversaw many innovative editorial and technical changes to content production. Her strategic role included attendance at all political party conferences, a variety of major Pan BBC contract negotiations and a number of strategic all-BBC editorial projects.

More recently Liz was asked to develop the BBC's local weather portfolio and in doing so discovered her passion for the genre. She initiated the commissioning of a multiplatform project *Wild Weather* (resulting in 12 regional TV documentaries) which was awarded the Royal Met Soc Michael Hunt Award in 2010. Liz recently secured the commissioning of 12 highly successful BBC1 documentaries on the 2012 drought. Delighted to be appointed Head of BBC Weather last year, Liz's role entails the strategic development of BBC weather output on all platforms – from local through to global and from online to mobile and IPTV. Liz is experienced in multiplatform broadcasting and communicating with audiences and is particularly interested in the delivery of science journalism in broadcasting. She aims to use her wide knowledge further develop BBC Weather forecasting and presentation – maximising the new platforms and technologies available whilst maintaining the trust, loyalty and engagement of all the BBC's weather audiences.

Professor Dominic Kniveton, University of Sussex, UK

Dominic Kniveton is Professor of Climate Change and Society at the University of Sussex. Originally focusing on the science and modelling of climate change his work encompasses studies of impact, vulnerability, adaptation, and climate resilience. In particular his recent research has explored the nexus of environmental change and migration. Recognition of his profile in this field is shown by invited participations in expert group meetings run by various agencies of the United Nations and UK government and his role as a consultant to the International Organisation of Migration to provide a state of the art review outlining the challenges and approaches to measuring the migration and environment nexus. A key part of many of these studies has been the integration of concepts and approaches from different academic disciplines to achieve research aims. For example in migration-climate studies his current research has embraced the use of qualitative data and analyses and agent based modelling to complement his scientific expertise. Dominic's other major research interest include humanitarian actions where he has been working to develop the use of innovative climate knowledge within local communities with such organisations as the Red Cross and Christian Aid.

Dr Reason Machete, University of Reading, UK

Reason L Machete is a Research Fellow in Mathematical Modelling for the Digital Economy at the Department of Mathematics and Statistics, University of Reading, within the Centre for Mathematics of Human Behaviour. He is also a Visiting Fellow at the Centre for the Analysis of Time Series, London School of Economics. He holds a DPhil in Nonlinear Dynamics and Chaos and an MSc in Mathematical Modelling and Scientific Computing, both from the Oxford Centre for Industrial and Applied Mathematics, University of Oxford. He has previously been a Mathematics Lecturer at the University of Botswana and a post-doc at the London School of Economics. His main research interest is to highlight and mitigate the effects of model error in probabilistic forecasting, with a special focus on weather and macroeconomic forecasting. He is keenly

interested in both the generation and evaluation of probabilistic forecasts, especially when the underlying dynamics are perceived to be nonlinear. Reason is married to Oabona, with whom he has twin boys and a girl child.

Dr Andy Morse, University of Liverpool, UK

Dr Andy Morse is a Reader in the School of Environmental Sciences, at the University of Liverpool. His background is in Atmospheric Physics. He works on the impacts of climate variability and climate change on human and animal health. He is best known for his work on the impacts of climate variability at seasonal scales on health, infectious disease, through integrating health impacts models with seasonal ensemble prediction systems. He has been active in transferring these skills across other disciplines and impacts areas. Most recently he has started to work on climate change impacts on disease using probabilistic approaches to investigate the uncertainties in projections.

PhD Atmospheric Physics, 1990, University of Manchester, UK

- Co-awarded the 2006 World Meteorological Organisation's Norbert Gerbier-MUMM International award
- Member Scientific Steering Committee of the ICSU Earth System Science Partnership (ESSP) joint project on Global Environmental Change and Human Health (2008 to date)
- Panel member of World Climate Research Programme's Working Group on Seasonal to Interannual Prediction [WGSIP] (2005 to date).

Mr Ken Mylne, Met Office, UK

Ken Mylne joined the Met Office from Oxford University in 1984 and initially conducted experimental research on pollution dispersion in the turbulent boundary layer. He then spent 6 years as a weather forecaster issuing aviation and shipping forecasts and warnings, before returning to research in ensemble forecasting, a technique used to understand the uncertainty in the weather forecast. He led the development of the Met Office's own ensemble prediction system, MOGREPS, which is now one of the world's leading operational ensemble forecasting systems. More recently he has focused more on the application of ensembles and integrating their use fully into the Met Office's operational production procedures, and in propagating the uncertainty in the weather forecast into an understanding of the impact on end-users to enable those users to make effective decisions in the face of uncertainty. Ken has been chair of the World Meteorological Organisation's Expert Team on Ensemble Prediction for the past 8 years.

Dr Warwick Norton, PCE Investors, UK

Warwick for the last 5 years has been Head of Meteorology for the Cumulus Funds at PCE Investors based in London. Here he provides expert weather analysis for the weather-related trading strategies of the Cumulus Energy Fund which trades European energy futures, and the Cumulus Fahrenheit Fund which trades US and European weather derivatives.

Previous to this position, Warwick has 20 years research experience in weather and climate variability at the Universities of Oxford and Reading. In 2001 he was a founding member of Weather Informatics Ltd which provided probabilistic medium and long-range weather forecasts and expert consultancy to energy and financial companies. He has a Ph.D. from the University of Cambridge.

Professor Tim Palme FRSr, University of Oxford, UK

Professor Tim Palmer is a Royal Society 2010 Anniversary Research Professor at Oxford University, and consultant at the European Centre for Medium Range Weather Forecasts, based in Reading. Tim's research is focussed on the dynamics and predictability of weather and climate, and he has pioneered the development of techniques to quantify flow-dependent uncertainty in weather and climate forecasts.

Dr Florian Pappenberger, ECMWF, UK

Florian Pappenberger is an expert in uncertainty analysis for flood models forced by ensembles of NWP and climate predictions. He is currently working at ECMWF as a Senior Scientist and is visiting professor at Hohai University (China). He has previously worked at the Joint Research Centre of the European Commission and at Lancaster University. In 2011 he was awarded the Arne Richter Award for Outstanding Young Scientists from the European Geosciences Union for his work on Hydrological Ensemble Predictions and in 2010 the Outstanding Editor Award of the Hydrology and Earth System Sciences Journal. His expertise in flood forecasting, hydrological modelling and uncertainty analysis is documented with over 60 peer reviewed publications. He has consulted for the Environment Agency of England and Wales on probabilistic flood forecasting and also works with Industry partners. He is also a chair of the international Hydrological Ensemble Prediction Experiment project (HEPEX, www.hepex.org). Florian is currently leading several large European projects on water scarcity and drought predictions (DEWFORA, GLOWASIS), developing a risk culture for Europe (KULTURISK) and European and global flood forecasting (GloFas, EFAS). He also works on global river modelling, ensemble verification and the impact of the uncertainty in land surface processes on seasonal predictions.

Professor Leonard Smith, London School of Economics, UK

Leonard Smith received his PhD (Physics) from Columbia University. Since 1992 he has been a Senior Research Fellow (mathematics) of Pembroke College, Oxford. As a Professor of Statistics at the London School of Economics he directs the Centre for the Analysis of Time Series and leads programmes within the Grantham Research Institute on Climate Change and the Environment. His research focuses on nonlinear dynamical systems, predictability, the role of probability in decision support, and the implications uncertainty, ambiguity and ignorance hold when relating mathematical results to reality. He is a Selby Fellow of the Australian Academy of Science and received the Royal Meteorological Society's Fitzroy Prize for his contributions to applied meteorology. Professor Smith is currently a member of the ASA Advisory Committee on Climate Change Policy (ACCCP) and a member of the Smith Institute's Scientific Committee.

Liz Stephens, University of Bristol, UK

Liz Stephens is a researcher in the School of Geographical Sciences at the University of Bristol. Her scientific interests focus on using flood inundation model ensembles to improve understanding of uncertainties in flood risk predictions. In particular, her work seeks to clarify how best to produce and assess uncertain predictions in the face of a lack of available data for these extreme events.

Reflecting on the usability of this uncertain risk information, Liz also aims to address the question of whether end-users of these predictions can actually make use of them. As part of the team involved in the Met Office's successful online 'Weather Game', she has begun to unravel the mysteries of how to present probabilistic forecasts to different audiences, and whether such provision improves decision-making ability.

Mr Arjunapermal Subbiah, RIMES: Regional Integrated Multi-Hazard Early Warning System, Thailand

Arjunapermal Subbiah is a lead international expert in the integration of climate forecast application in development processes. As the Director of RIMES, he provides strategic direction and leadership for translation of policies, established by the RIMES Council, into programs.

Subbiah has 25 years of experience in assisting countries to develop multi-institutional and multi-disciplinary mechanisms to manage climate-related hazards. He has guided the Governments of Bangladesh, India, Indonesia, Mongolia, the Philippines and Vietnam in developing institutional mechanisms and capacities for the generation, interpretation, translation and communication of climate and flood forecasts, with lead times of 5-10 days, 20-25 days, and 1 month and beyond, for local application by farmers and disaster managers for disaster mitigation.

Subbiah held senior positions with the Asian Disaster Preparedness Center as Director, Climate Risk Management and the Government of India as Director, Ministry of Home Affairs from 2001-2002, Deputy Secretary of the Ministry of Rural Development and Environment from 1993-2001, and Under Secretary, Ministry of Agriculture from 1982-1992. He was actively involved in policy formulation and implementation of natural disaster preparedness, response, rehabilitation and reconstruction projects, and in the preparation and implementation of contingency crop plans to manage climate variability-associated risks on agriculture. He had also worked in drought mitigation and prevention of desertification in the Sahel Region, Africa.

Subbiah holds a Master's degree in Agricultural Entomology from Madurai University, India. He is trained in Climate Risk Management (East-West Center, USA), Disaster Risk Management (Sweden), and Disaster Management (ADPC, Bangkok).

Ms Emma Visman, Humanitarian Futures Programme and Kings College London, UK

Emma has been involved with the Humanitarian Futures Programme (HFP) at King's College London since 2006, leading the programme's work on strengthening dialogue between scientists and those with humanitarian responsibilities regarding issues of future vulnerability. Her current activities include coordinating an exchange project between climate scientists and humanitarian organizations, with demonstration studies underway in Kenya and Senegal. In 2011 she received a two-year Knowledge Exchange Fellowship from the Natural Environment Research Council, focused on collating learning about approaches which support dialogue between the providers and users of science from across different scientific disciplines and geographic regions, identifying space for developing more systematic science-humanitarian dialogue, and engaging with two ongoing NERC-funded research projects, one on climate science (EQUIP) and one on earthquake science. Previously Emma worked for Save the Children UK in Iraqi Kurdistan, Somalia, Angola, Rwanda and the Democratic Republic of Congo, for the foreign affairs think-tank, Saferworld, and has undertaken consultancies with a range of humanitarian and development organizations including UK Department for International Development, ActionAid, the Coalition to Stop the Use of Child Soldiers and the British Council.

Professor Peter Webster, Georgia Tech, Atlanta, USA

Professor Webster's career may be divided into two parts: Exploring the dynamics of low-frequency atmospheric circulations such as monsoons and El Nino and determining the predictability of the precipitation associated with these phenomena. More recently, he has attempted to use this theoretical insight to the generation of forecasting models of hazards (floods and tropical cyclones) and the transfer of these modules and their output to the people of the developing world, from government organizations to the villagers, especially in South Asia.

Webster is a professor in Earth and Atmospheric Sciences at the Georgia Institute of Technology. During his academic career he has mentored and graduated 28 doctoral students. He has published over 160 peer reviewed articles and two text books. He has been recognised widely receiving the Mason Gold Medal (2012) and the Adrian Gill Award (2003) from the Royal Meteorological Society (2003). In addition he received the Carl-Gustav Rossby Gold medal (2004) and the Jule G Charney Research Award from the American Meteorological Society. Webster is a fellow of the Royal Meteorological Society, the American Geophysical Society, the American Meteorological Society and the American Association for the Advancement of Science.

NOTES

NOTES

Participant List

Correct as of 28 September 2012

Title	Forename	Surname	Hons	Organisation	Country
	Hannah	Arnold		University of Oxford	UK
Professor	Paul	Bates		University of Bristol	UK
Professor	Matthew	Baylis		University of Liverpool	UK
Mr	Bernd	Becker		Met Office Hadley Centre	UK
	Tracey	Brown		Sense About Science	UK
Dr	Melvin	Brown		Industrial Mathematics KTN	UK
Dr	Simon	Buckle		Imperial College London	UK
Mr	Denis	Buckley		Highfield Lodge Agronomy	UK
Dr	Carlo	Buontempo		Met Office	UK
Dr	Sal	Burgess		Defra	UK
Professor	Andy	Challinor		University of Leeds	UK
Dr	Rosalind	Cornforth		University of Reading	UK
Dr	Susanna	Corti		ECMWF	UK
Professor	Judy	Curry		Georgia Tech, Atlanta	USA
Dr	Kirstine	Dale		Met Office	UK
Dr	Jonathan	Day		NCAS	UK
Professor	David	Demeritt		King's College London	UK
Professor	Suraje	Dessai		University of Leeds	UK
Dr	Christopher	Ferro		University of Exeter	UK
Mr	David	Gifford			UK
Dr	Isla	Gilmour		DE Shaw & Co Ltd	UK
Miss	Nicola	Golding		UK Met Office	UK
Dr	Paul	Green		National Physical Laboratory	UK
Dr	Renate	Hagedorn		Deutscher Wetterdienst	Germany
Professor	Paul	Hardaker		Chief Executive of the Institute of Physics	UK
Dr	Ed	Hawkins		University of Reading	UK
Dr	Jeremy	Hess		Emory University Department of Emergency Medicine	USA
Mr	Timothy	Hewson		Met Office / ECMWF	UK
Professor Sir	Brian	Hoskins	CBE	Imperial College London and University of Reading	UK
	Liz	Howell		Head of BBC Weather	UK
Dr	Matthew	Huddleston		Met Office	UK
Professor	Dominic	Kniveton		University of Sussex	UK
Professor	Peter J	Lamb		University of Oklahoma	USA

Dr	Reason	Machete		University of Reading	UK
Mr	Dave	MacLeod		University of Liverpool	UK
Dr	Oscar	Martinez-Alvarado		University of Reading	UK
Dr	Anthony	McAllister		University of the Third Age	UK
	Luis Carlos	Miranda Trujillo		Humboldt-Universität zu Berlin	Germany/ Mexico
Professor	John	Mitchell	OBE	Met Office	UK
Mr	Rupert	Morris			UK
Dr	Andy	Morse		University of Liverpool	UK
Mr	James	Murphy		Met Office	UK
Mr	Ken	Mylne		Met Office	UK
Dr	Warwick	Norton		PCE Investors	UK
Professor	Tim	Palmer	FRS	University of Oxford	UK
Dr	Florian	Pappenberger		ECMWF	UK
Mr	John	Parker		The Economist	UK
Miss	Louise	Parry		University of Bristol	UK
Dr	Samantha	Rawlings		University of Reading	UK
Dr	Daniel	Rowlands		Cumulus/PCE Investors	Uk
Dr	David	Sexton		Met Office	UK
Mr	Anders	Sivle		Norwegian Meteorological Institute	Norway
Professor	Leonard	Smith		London School of Economics	UK
	Liz	Stephens		University of Bristol	UK
Mr	Arjunapermal	Subbiah		RIMES: Regional Integrated Multi-Hazard Early Warning System	Thailand
Dr	Janakiraman	Subburathnam		Centre for Development of Advanced Computing	India
Dr	Emma	Suckling		London School of Economics	UK
Mr	Roger	Tattersall		University of Leeds	England
Professor	Martin	Todd		University of Sussex	UK
Mrs	Maureen	Vilar		climateprediction.net	UK
Ms	Emma	Visman		Kings College London	UK
Mr	Bob	Ward		Grantham Research Institute on Climate Change and the Environment	UK
Dr	Keith	Weatherhead		Cranfield University	UK
Professor	Peter	Webster		Georgia Tech, Atlanta	USA
Dr	Antje	Weisheimer		University of Oxford and ECMWF	UK
Professor	Robert	Wilby		Loughborough University	UK