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THE ROYAL SOCIETY

Introduction

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The floods in East Anglia early in November 2001, following those of autumn 2000 (the wettest autumn for England and Wales since records began in the 1760s), could not have provided a more timely reminder of the importance of flood risk and concerns for the impact of climate change. On 21 and 22 November 2001, a full audience attended The Royal Society's Discussion Meeting on Flood Risk in a Changing Climate, opened by Eliot Morley, Secretary of State with responsibility for floods at the Department for Environment, Food & Rural Affairs (DEFRA). Speakers from the USA and Europe joined UK experts to review scientific progress and the outstanding challenges underlying flood-risk management. The papers presented at that meeting form the basis of this issue, together with a concluding discussion summarized by Lord Hunt. An important contribution to the meeting was a set of 31 posters, ranging from an analysis of extreme floods in Venezuela to issues of operational management of the Thames Barrier. Space precludes their inclusion here, but we include poster abstracts at the end of this issue.

What is the reality of climate change? The first three papers address the modelling of global climate and associated scenarios of climate change, and review the evidence of climate change in the UK rainfall and river-flow data. Senior *et al.* (2002) provide a reminder that, while models are still far from estimating with certainty precipitation and sea-level rise, there is consensus between models that, arising from greenhouse-gas emissions, the UK can expect increased winter rainfall, probably of increasing intensity, and increasing sea levels. Evidence from the historical record is mixed. Osborn & Hulme (2002) show that the frequency of intense rainfall has indeed increased significantly over the last 40 years, as has the frequency of multiple days of heavy rain. However, Robson (2002) finds no clear evidence of longer-term trends in flooding. Recent floods, she reports, do not look outstanding compared with flood data from the last 120 years. There is a clear conclusion that climate is varying, and in a way which is consistent with climate-model predictions; however, there is no unambiguous observational evidence to prove that recent floods are due to climate change.

Papers on rainfall point to new developments in using radar for rainfall measurement (Collier 2002), leading to improved accuracy and spatial resolution, and in assimilating observational data from radar and satellites with meteorological models, to improve rainfall forecasts (Gupta *et al.* 2002). Using these new methods, for example, the University of Arizona produces global forecasts of tropical rainfall, available on the Web. New developments in statistical approaches to floods are presented. Reed (2002) discusses UK experience and the recent (1999) *Flood estimation*

One contribution of 18 to a Discussion Meeting 'Flood risk in a changing climate'.

handbook (FEH), and Cox *et al*. (2002) present in particular new methods of improving estimates of extreme floods at a given site, including quantifying the uncertainty associated with the flood estimates. It is reassuring to practitioners to note that the results presented are similar to those in the FEH.

Moving to the modelling of rainfall-run-off processes, Wheater (2002) highlights advances and limitations of modelling rainfall-run-off for flood planning and management. New methods have solved the problem of modelling continuous flows from rainfall (observed or simulated) for catchments with no streamflow data, thus providing the basis of a new national methodology for flood design. This must be supported by rainfall simulation models which build on the improved observations of spatial rainfall from radar. Representing urban and rural land use and land-management change is a major challenge. Technical development is needed to represent land-use change more effectively in hydrological models. A new generation of decision support tools is likely to focus on data assimilation and quantification of uncertainty. Young (2002) reviews developments in modelling for the important operational problem of forecasting floods in real time. Current data-based models are efficient at extracting information from the available rainfall and flow data, and can readily incorporate techniques for taking account of forecast errors in updating the model. Thus a model fitted to just 30 days of data for the river Hodder could provide a good forecasting tool for other periods and larger flows. Verworn (2002) developed further the issues of urban flood management. Advanced real-time control systems have been developed for urban centres to use the storage capacity of storm drains and underground storage tanks more effectively through active control of gates and other flow-control structures, but these have not been widely adopted in practice. New concepts of sustainable urban drainage systems have been developed to reduce the impact of urban development on floods generated from run-off and to mitigate pollution; examples now implemented in Germany include channelling roof and road drainage to engineered soakaways rather than piped drainage systems.

Considering next coastal and estuarine flooding issues, Townend & Pethick (2002) describe the linkages between the way tides are propagated and the shape of estuaries, and hence the response to rising sea levels, with estuaries moving landwards. This raises major management issues. Do we protect our shorelines, or manage retreat? Improved conceptual models of geomorphological change, supported by numerical modelling, are being used to analyse management solutions which included managed retreat. Results are reported from a major study of the Humber. Many practical problems are associated with managed retreat. These include issues such as public perception of the need to remove flood protection, stakeholder participation in the release of land for flood inundation, and the constraints imposed by current conservation legislation. A narrow interpretation of habitat protection can conflict with the implementation of a more sustainable long-term solution. Battjes & Gerritsen (2002) review the Dutch experience of safety standards for coastal protection, and the current state of the art of hydrodynamic and statistical modelling for coastal flooding, including storm surge and wave effects. They also describe new approaches to risk assessment of potential inundation due to dyke failure, currently being developed in the Netherlands.

The final set of papers address broader perspectives of flooding. The paper by Poff (2002) explains the importance of flood regimes and the inundation of flood plains for the diversity and productivity of species in ecosystems bordering rivers. He discusses

the importance of major floods in re-establishing connections with severed flood plain and riparian wetlands in human-dominated river valleys and the guidance available to predict impacts of change. Tapsell *et al*. (2002) discuss the socioeconomic aspects of flooding. They present survey evidence that the psychological impacts of floods are long-lasting, and undervalued, and argue that a cost–benefit approach to flood protection can lead to protection of the affluent (who live in expensive properties) at the expense of the disadvantaged (who do not). They produce in their paper a disturbing analysis that showed that the location of key emergency facilities and vulnerable households on flood plains was widespread, with major implications for planning and emergency management. Evidently, improved awareness of areas at risk from flooding is required, as is more effective linkage to the planning processes. Finally, Fleming (2002) introduced the November 2001 Institution of Civil Engineers report on flood risk management to DEFRA. This wide-ranging report highlights technical issues, such as the need for better observational data on high river flows, improved decision support tools and the need for greater take-up of model-based risk assessment. It also stresses manpower issues (shortages of trained manpower in the flood defence area), social impact issues (as noted above) and administrative barriers to more effective flood management. These include problems with the current system of local responsibility for expenditure on river flood defences, and in the diverse responsibilities for water management in urban areas.

The concluding discussion, led by Lord Hunt, was stimulating and wide ranging, and included topics as diverse as estimating probable maximum floods, and different perceptions of the role of the insurance industry in providing cover for properties at risk. This issue concludes with Lord Hunt's personal view of some of the more important issues raised during the meeting (Hunt 2002). Overall, there was a strong sense that the meeting had succeeded in identifying an important set of scientific, technical and administrative challenges at a timely moment to influence the national political and research agendas.

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