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Climate related hazards: Prevention, risk management, mitigation and forecasting

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CLIMATE RELATED HAZARDS: PREVENTION, RISK MANAGEMENT, MITIGATION AND FORECASTING

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The hazards

Much of this contribution to the symposium is written from the perspective of flood management but issues on risk management are common to natural hazards more broadly.

Here we define a hazard as a situation that has the potential to cause harm. Hence we take an anthropocentric viewpoint (no humans, no hazards and certainly no risk). Hydro-meteorological hazards in their most generic form derive from precipitation, wind speed, thermal conditions and transport of air-borne pollutants and pathogens. Fluctuations in these quantities may occur over a wide range of temporal and spatial scales. Human life, society etc is generally well adapted to the status quo – the climatic average and “normal” variability; it is the variations beyond the normal that mainly give rise to the natural hazards such as:

- floods (flash-floods, extensive floods of lowland plains, groundwater floods),
- avalanche (snow / rock),
- landslide, mud and debris flows – often in conjunction with floods
- storm surge, storm wave leading to inundation of coasts and estuaries
- windstorm and tornado
- drought

This contribution to the symposium concentrates on issues associated generally with short-term precipitation extremes at a variety of spatial scales. In flooding, the greatest risk to life occurs in unexpected flooding whether from flash flooding from rainfall or from large waves close to the shoreline. Heavy rainfall also can trigger land instabilities, with landslides posing a substantial risk to life and property in certain areas of Europe. Economic and property damage is often most severe for events with a large spatial scale – major basin floods or coastal surges. However, triggering mechanisms for floods can also depend upon longer term climatic conditions such as seasonal accumulations of snow or, for landslides, the season-scale accumulation of rainfall. The social and economic impacts of natural hazards are well documented elsewhere; see for example the recent report of the European Environment Agency (2003).

Prevention and mitigation

The word “prevention” perhaps should not be used for climate related natural hazards since technologies are not available to influence the meteorological conditions that cause the hazards and any actions to reduce human-induced climate change will only have an influence in the long-term. Nevertheless, “flood prevention” for example was a widespread policy aim in the last century. In Hungary the national concept of “flood fighting” portrays the struggle between the community and the natural forces of the river and this is similar to the notion in many countries of providing flood defence, protection or prevention. All these terms indicate a philosophy of human control over nature and the protection of property against the “common enemy” of the elements.

Now the position is that of flood risk management (Samuels *et al.*, 2005); this builds on the developments in the research community, sponsored nationally and at a European level. Typically a strategy for flood risk management will combine a number of mitigation measures. The design of effective mitigation measures requires a sound understanding of the physical and social factors which contribute to the overall risk. For example, the recently completed IMPACT project of FP5 examined processes which operate in extreme floods (www.impact-project.net); the outcome of the research on the failure of embankments is that the best performing models are now available from Europe. The FP5 Action MITCH extracted commonalities from completed FP4 research on floods, droughts and landslides (see Fuchs (2006) or www.hrwallingford.co.uk/Mitch/default.htm). The FLOODsite project is undertaking research on both physical and social issues to provide tools and techniques for risk management with training and dissemination strategy to facilitate implementation and uptake of the research outcomes.

Risk management

The benefit to society from research on climate related hazards will come through better risk management. In discipline of risk

management, “risk” is no longer taken as a synonym for “hazard” but is a combination of both the hazard and the consequences that follow from that hazard happening.

Over the past decade or so concepts around hazard and risk have been clarified, providing a clearer picture of the rôles in risk management of the natural hazard processes and the social aspects of the impact of hazards on people, property and the environment. There are many common themes to risk management regardless of the type of hazard that causes the risk. Principal amongst these are

- Applying the analytical model of source, pathway, receptor and consequences
- Describing the hazard in terms of frequency and quantified physical measures
- Identifying areas, communities, physical or environmental assets, social structures, etc (the “receptors”) which are exposed to the hazard
- Quantifying the vulnerability of the receptors to harm in terms of susceptibility to various types of damage and a “value” for that damage.

For climate related hazards little can be done with current technologies for affecting the source in terms of strength or probability of occurrence. Thus risk management measures are directed at other aspects of the overall risk through

- altering the characteristics of the pathway
- reducing the exposure of the receptors to the hazard or
- reducing the vulnerability of the receptors to experiencing damage.

These actions collectively are termed “risk management measures” in the FLOODsite Language of Risk (FLOODsite, 2005). Measures which address risk through controlling exposure and vulnerability will be largely non-structural in nature whereas altering the pathway will usually be through structural intervention in the system. Research in FLOODsite has identified the importance of understanding the nature of the

risk management process and the rôles and responsibilities of all the actors in the decision making (Müller & Schanze, 2005). The portfolio of risk management measures may be classed broadly as those applied in preparation for any event (e.g. spatial planning, contingency planning, and defence infrastructure), emergency measures during an event, and, support and recovery measures after the event.

Understanding and identifying climate-related hazards and aspects of risk management has been undertaken in many EC research projects, see the projects to FP5 listed in Samuels (2003) and the summary by Fuchs (2006) with research continuing in FP6 particularly in the FLOODsite IP and the Armonia STREP on multi-hazards.

Flood forecasting

Current research on flood forecasting at a European level has a long patrimony, building on projects in FP2, FP3, FP4 and FP5. The ACTIF Accompanying Measure in FP5 acted as a “Cluster” of eight FP5 projects on flood forecasting. The projects represent the state-of-the art in their areas with innovations in a variety of topics including:

- innovative technologies for space-borne and ground-based monitoring;
- the estimation of precipitation in near real time at a global scale
- assimilation of data from a variety of sources with different characteristics into numerical weather prediction and hydrological models
- new and improved modelling techniques;
- the linkage between meteorological and hydrological models;
- spatial recognition and indicators for current state of natural hazards;
- improvements in the dissemination of forecasts and warning;
- practices for emergency awareness, preparedness and operations at both the institutional level and with the individual citizen.

Three projects, ACTIF, FLOODMAN and Flood Relief sponsored a common end-of-project international conference in October 2005. The proceedings of this event cover current issues in flood forecasting worldwide and are available through the ACTIF website (www.actif-ec.net).

Research influences on policy and practice

Policy and practice on risk management (flood risks in particular) is responding in a variety of ways to knowledge and new techniques arising from research and the need to continue to invest in knowledge; three examples are given below.

The European approach on Flood Risk Management has undergone significant development since 2001. In September 2003 the European Environment Ministers produced the document “Best practices on flood prevention, protection and mitigation”. In July 2004 a Commission Communication was published from the Commission relating to flood risk management and subsequently an Action Programme is under development. The action programme includes: legislative proposals for a new Directive requiring flood risk management plans, research and information exchange activities and funding possibilities for the proposed actions. The action programme and the directive now being drafted recognise the importance of research in improving knowledge and understanding of the management of flood risks.

At a national level, the UK Office of Science and Technology (OST) commissioned the Flooding Foresight project to inform public policy and expenditure by researching the drivers, responses and scenarios for flood risk over a timescale of about 100 years. Flood risk was analysed at a 10km scale for four socio-economic scenarios, which were linked to global emissions scenarios and simulations of future climate. Drivers of flood risks were identified and ranked under each of these scenarios and the potential flood damages estimated for the 2080s. Substantial differences emerged between the scenarios with the damage increasing in all

scenarios if current policies are maintained. Nationally, the current annual flood damage is estimated as about €1 Billion, with this rising to over €30 Billion without additional mitigation strategies in the worst scenario. Future flood risks depend strongly on assumptions on global emissions of greenhouse gases; this provides a clear link between international policy and impacts at the national scale. The report (OST, 2004) poses many questions to policy makers such as:

- Should the increasing levels of flood risk be accepted or actions taken to reduce them?
- How important is managing climate change to the risks faced from flooding and how best can this be achieved?
- How should land be used in balancing the wider economic environmental and social needs against creating a legacy of flood risk?
- What is the balance between societal responses to flood risk and the implementation of bigger structural defences?
- Who should pay for flood defence – the balance between government, developers, the individual and insurance?

In FP6, the ERA-NET coordination actions are bringing further structuring of the European Research Area with actions continuing through FP7. In the context of research on flooding issues, the ERA-NET CRUE aims to provide greater cooperation between national research programmes on flooding which together spend in excess of €30 Million per annum in the 25 Member States. The vision for the CRUE is to develop strategic integration of research at the national funding and policy development levels within Europe to provide knowledge and understanding for the sustainable management of flooding risks at the river basin and coastal process cell scale. CRUE is also addressing the pressing need to improve the dissemination of existing research results to derive public benefit from past investment in the generation of knowledge and understanding.

Research challenges

The research needs below concentrate on flooding as others at this symposium contribute topics on landslides and drought. These research challenges were drafted following the workshop organised in Brussels by DG Research on 10 October 2005 in response to the summer 2005 flooding. The overall objective is to support sustainable economic and social development without increasing property or people at risk from climate-related natural hazards. Important research challenges remain on flooding issues and processes which are related in particular to extreme events and combinations of natural hazards that have a common driver, for example, landslides and floods generated by rainfall.

Databases

- European database (with guidance and protocols) for extreme floods allied with other natural hazards recording processes in operation, damages, human and social impacts
- European meta database on natural hazards research results (project deliverables, models, publications)

Multi-hazard issues

- Generation of sediment and debris in extreme floods including
 - indicators of sources, likelihood and quantity of debris and sediment generation
 - sediment load from landslides and mud flows,
 - beach / foreshore mobilisation by storm waves
 - floating debris (for example trees, urban trash and vehicles) and
 - large dense material (including boulders and masonry from failed structures)
- Propagation and fate of debris and sediments in highly unsteady conditions including
 - Effects of debris and sediments on the performance of flood defence infrastructure, blockage of river structures, or damage to properties

- Impact of short-term morphological change on estimated extent and magnitude of flood hazard (e.g. major accretion in river systems or loss of coastal foreshore)
- Means of identifying areas at risk from debris and sediment effects
- Joint occurrence (incl. uncertainty) of related natural hazards
- Probabilistic real time risk forecasting of multi-hazard events
- Feasible flood management options and activities accounting for the multi-faceted nature of extreme events

Uncertainty issues

- Combination and propagation of all sources of uncertainty
- Contribution of uncertainty to overall assessment of risk
- Communication of uncertainty to non-scientists

Infrastructure performance

- Identification, understanding and parameterisation of failure modes and mechanisms
- Develop techniques and tools for reliability analysis
- Non-intrusive technologies to measure defence condition
 - Measurement technologies for defence condition (static)
 - Real-time monitoring technologies for changes in defence strength
- Forecast pathway performance including
 - probability of failures (using real-time monitoring of condition) and effects of debris on system capacity (including blockage of bridges and structures and deposition)

Modelling

- Improved probabilistic forecasting of flood sources (precipitation, ocean waves, storm surges) based on coupled modelling
- Flood prediction in ungauged basins

Flooding in urban areas

- Storm sewerage system performance under intense rainfall or wave overtopping conditions
- Propagation of floods through urban areas from all sources of flood water
- Land use impacts on flooding
- Fate of flood-borne pollutants and pathogens in the urban environment
- Direct impacts of wave, surge and tsunami inundation on people and property
- “Broad-scale” models of urban drainage systems to enable management strategies to be developed at city scale considering of all flood sources and pathways within the urban area

Future scenarios for natural hazards and risk including climatic forcing

- Improved regionalisation at spatial and temporal scales of interest for natural hazards - both deterministic and statistical downscaling
- Changes in extremes and parameters of probabilistic functions as used for technical / engineering design
- Better coverage of feed backs within elements of the terrestrial system and between the terrestrial and atmospheric systems (e.g., with land-use or water supply)
- Scenarios of future management of natural hazards
 - governance, social, policy, technology
 - linkage to climate scenarios

Socio-economic and institutional aspects of risk management from natural hazards

- Driving factors and growth indicators of flood risk
- Influencing public understanding and awareness of direct and indirect water-driven risks and their uncertainty
- Valuation methods and tools for flood risk (socio-economics and ecology)
- Institutional issues arising from flood disasters and failures in flood management

- Identifying “tolerable” flood risk taking account of economic and social pressures and contingency plans for extreme events
- Influence of governance strategies on long-term change and management of flood risks
- Influence of land use and management policies on long-term flood risk
- Adaptive strategies (incl. resilience) to manage risk from floods and associated natural hazards
- Institutional arrangements for disaster management and civil protection
- Account for real-time distribution of exposure and vulnerability of receptors

Uptake and implementation of research advances (in FP5, FP6 and FP7)

- Facilitate uptake of flood risk management methodology developed in FP6 for risk management of all hazards
- Identifying and overcoming barriers to end-user acceptance and implementation of research outputs
- Disseminate European flood RTD outcome in a user friendly web portal linked with information on relevant policy demands and end user requirements
- Moving beyond communication and dissemination to operational implementation
- Demonstration and training of research advances in practice
- Practical risk minimisation methods

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Concluding remarks

Patterns of settlement, land use, flood defence and drainage in Europe have a significant legacy from previous generations of interventions in the natural systems of rivers and flood plains. Seeking the path of sustainable development implies that our generation’s risk management practices should not place additional burden on future generations. Hence risk analysis for flood management in current and future conditions should be undertaken to inform policy choices, land use planning and public investment in infrastructure. Past research at national and European level on climate related hazards has brought benefits to European citizens through more reliable means of forecasting and warning, identification of areas at risk of flooding, landslide and avalanche, and, methods for mitigation of the hazards. Scenarios for future climate in many parts of Europe show a significant impact on the hydrological cycle with variations at a range of spatial and temporal scales. Investment in research is essential to provide understanding of climate related natural hazards, whether they arise from trend, regional and seasonal changes or extremes of precipitation and drought.

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