T701157CEE 18/01/07 12:01 Page 3

EUROPEAN COMMISSION

International Workshop

Climate Change Impacts on the Water Cycle, Resources and Quality

Research-Policy Interface

25 - 26 September 2006

Scientific and policy report

edited by

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Climate Change and Natural Hazards series 8

2007 Directorate-General for Research EUR 22422

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Luxembourg: Office for Official Publications of the European Communities, 2007

ISBN 92-79-03314-X

Printed in Belgium

PRINTED ON WHITE CHLORINE-FREE PAPER

TABLE OF CONTENTS

FOREWORD

Acknowledgement

With special thanks to Valérie Dissard for her contribution to the editing and publication of this catalogue

PREFACE

Climate change resulting from human activity is already starting to have negative impacts on our way of life. It is likely that climate change is to blame for the increasing frequency of natural hazards (floods, heat waves, droughts, forest fires, etc). There is growing evidence that temperature rises and changing precipitation patterns will exacerbate the already acute water shortage problem in the southern and south-eastern regions of Europe. Changes are expected in the frequency and intensity of droughts and floods, and these could cause significant financial and human loss throughout Europe.

Climate change could have major consequences on the quantities and quality of fresh water available in the future. Interdisciplinary research is needed for us to build knowledge and devise strategies for the sustainable development of different regions in a changing climate. It will also provide results that can feed into policy development.

The floods and droughts of 2005 and the heat wave and droughts of 2006 were a major concern in Europe. The Commission is taking action in response to these events, and would like to show citizens that research is being undertaken on the issues they are concerned about and that the results can support policies and thus make us better prepared to face environmental change.

Climate change has become an increasingly important area in the EU's framework research and development (R&D) programmes. It is a priority in the forthcoming 7th Research Framework Programme, which will run from 2007 to 2013.

In this context, three Directorates-General of the European Commission - Research, Environment and the Joint Research Centre - jointly organised a workshop in Brussels on 25-26 September 2006 to discuss climate change impacts on the water cycle, and to review research and policy and thus pave the way for the development of an adequate policy-research interface.

The workshop tied in well with international discussions. The impact of climate change on water, adaptation and mitigation strategies was a key component at the second meeting of the Parties to the Kyoto Protocol (COP/MOP 2) in Nairobi from 6 to 17 November 2006. The issue will also be discussed in depth at the International Conference on Climate Change and the Water Dimension, which will be held in Berlin on 12-13 February 2007 under the German Presidency.

The workshop in Brussels had a strategic impact on the research and policy communities in that it defined interactions between science and policy on climate change and water and discussed what scientists know about climate change - and the areas of uncertainty - and ways in which scientific outputs could be translated into policies. Whether you are active in – or interested in – the scientific or political sides of this important topic, we trust you will find this report of the results of the workshop of considerable interest.

Mogens Peter CARL	***Roland SCHENKEL***	***José Manuel SILVA RODRÍGUEZ***
Director-General for Environment	Director-General Joint Research Centre	Director-General for Research

INTRODUCTION AND OBJECTIVES

INTRODUCTION

Climate models projections based on different scenarios of future greenhouse gas emissions indicate a warming of 1.4 to 5.8ºC over the next century. The projected change in climate will significantly impact the hydrological cycle. A warmer climate will increase evaporation and the intensity of water cycling, and result in greater amounts of moisture in the air. The magnitude and frequency of extreme weather events are expected to increase, and hydrological extremes such as floods and droughts are likely to be more frequent and severe over most of Europe. At the same time, in some regions the rising demand for water in sectors such as agriculture and energy production may further increase Europe's vulnerability to drought. In addition to its effects on water quantity, climate change is likely to affect water quality by bringing about physico-chemical, biological and hydro-morphological changes.

Research into climate change impacts on the water cycle improves the understanding and assessment of key drivers and their interactions. This research will help to identify risks and uncertainties and to develop measures for mitigation and adaptation. There is a growing consensus that climate change is a serious and long-term challenge with potentially irreversible consequences, and thus it has become one of the main priorities within the European Commission. Consequently, a wide spectrum of research projects related to climate science, impacts, adaptation and mitigation have been supported by the European Union. This effort will be continued under the 7th Framework Research Programme (FP7), where climate change is one of the 4 activities in the Environment thematic area of the Cooperation Scientific Programme. Research directed towards improving the understanding of process and prediction will be specifically taken into account and linked to emerging needs and policy-relevant research, such as drought risk assessment in Europe and the incorporation of climate change impacts into water policies. In addition, results from European research make an important contribution to the Intergovernmental Panel on Climate Change (IPCC) and help to honour international commitments such as the UN Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol.

Current EU water policies (e.g. Water Framework Directive) have a planning cycle reaching 10-30 years in the future. Within this timescale, the projected climate change and its impacts on the water cycle and water resources are likely to lead to higher environmental, ecological and socio-economic pressures and costs in Europe. The question has been raised as to whether the present water policy framework covers issues of climate change, and if there are opportunities for developing adaptation measures to climate change policies within the frame of existing EU water policy.

OBJECTIVES

The workshop brought together scientists and water managers in an effort to gain an overview of science and policy challenges as regards climate change impacts on water, and to review the key results of ongoing (FP6) and completed EU projects on climate change and water. It also explored whether the current scientific outcomes are sufficiently mature to be taken on board in policy development, as well as suggesting priority research topics that should be addressed at European level in the future.

The objectives of the workshop were to:

- review the key results of ongoing (6th Research Framework programme - FP6) and completed EU projects dealing with climate change impacts on the water cycle;
- review adaptation strategies implemented in different Member States;
- explore whether the current scientific outcomes are sufficiently mature to be taken on board in policy development;
- define gaps in knowledge, as well as needs from and for policy;
- define priority research topics that should be addressed at European level as strategic input into the implementation of FP7;
- define the agenda and an adequate platform for establishing interactions between science and policy in the field of climate change and the water cycle;
- define long-term research priorities in the present research and policy context.

By successfully meeting the above objectives, the workshop represented a milestone in defining key research and policy elements related to the assessment of climate change impacts on the water cycle, quality and resources, and in setting the interface between science and policy in this area.

The workshop represents a step within a process. In this sense, the conclusions of the workshop will be used as input for the international symposium on “Climate Change and the European Water Dimension” to be held during the German Presidency of the European Union in Berlin in February 2007.

Details of this workshop, including speakers' presentations, are available at the internet site: http://cordis.europa.eu/sustdev/environment/ev20060628.htm.

EXECUTIVE SUMMARY AND ABSTRACTS

EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

1 – Introduction

Climate models projections based on different scenarios of future greenhouse gas emissions indicate a warming of 1.4 to 5.8ºC over the next century. The projected change in climate will significantly impact the hydrological cycle. A warmer climate will increase evaporation and the intensity of water cycling, and result in greater amounts of moisture in the air. The magnitude and frequency of extreme weather events are expected to increase, and hydrological extremes such as floods and droughts are likely to be more frequent and severe over most of Europe. At the same time, in some regions the rising demand for water in sectors such as agriculture and energy production may further increase Europe's vulnerability to drought. In addition to its effects on water quantity, climate change is also likely to affect water quality by bringing about physico-chemical, biological and hydro-morphological changes.

Projections of climate change impacts on the availability and quality of water include a high level of uncertainty. Moreover, what scientific knowledge there is fragmented and not readily accessible to decision-makers. This makes it difficult to establish a long-term strategy and to identify appropriate adaptation measures. To address these challenges, the European Commission's Directorates-General for Research (DG RTD), Environment (DG ENV) and the Joint Research Centre (DG JRC) organised the workshop "Climate Change Impacts on the Water Cycle, Resources and Quality – Research-Policy interface". The workshop brought together scientists, water managers and policy-makers in an effort to gain an overview of science and policy challenges in the field of climate change and the water cycle, and to review the key results of ongoing and completed EU research projects in this area. The workshop aimed to explore whether the current scientific outcomes are sufficiently mature to be taken on board in policy development, as well as to suggest priority research topics that should be addressed at European level in the future. The event represented a milestone in defining key research and policy elements related to the assessment of climate change impacts on the water cycle, quality and resources, including discussions on how to adapt.

The event was organised by three EC Directorates-General, which is a clear message of the importance of this issue, and of the need to develop more coherent and synergistic research and policy approaches to meet these challenges. The workshop created an excellent arena for communication between the scientific community and policy-makers. Through its reactive discussions, the meeting was perceived as a kick-off event calling for improved communication between science and policy-makers in the future.

The workshop included five sessions, which examined different scientific and policy areas, followed by round-table discussions. This executive summary highlights the main points of the discussions held during the workshop. Details on the presentations are given in the form of extended abstracts.

2 – Research dimension

Research on climate change impacts on the water cycle, resources and quality improves the understanding and assessment of key drivers and their interactions with other human activities and the combined consequences. The knowledge produced is needed to manage and mitigate risks and uncertainties and to develop appropriate measures for adaptation. As climate change has become one of the main priorities of the European Commission over the last few years, a wide spectrum of research projects related to climate change, impacts, adaptation and mitigation have been supported by the European Union. This effort will continue under the Seventh Framework Programme for Research – FP7, where climate change is one of the four activities in the Environment thematic area of the Scientific Programme. The input provided by the FP7 will be a real incentive for Europe and the research community to look at the climate-water interactions both at global and at regional level. Research directed towards improved process understanding and prediction will be specifically taken into account, and linked to emerging needs and policy-relevant research, such as drought risk assessment and the incorporation of climate change impacts and adaptation strategies into water policies.

Results from research are also the bedrock of the Intergovernmental Panel on Climate Change (IPCC). The role of the IPCC is to advise governments on the most responsible courses of action to implement international commitments such as the UN Framework Convention on Climate Change (UNFCCC) or the Kyoto Protocol. These recommendations are based on the best available scientific, technical and socio-economic information on climate change worldwide.

The different views expressed and the results presented at the workshop showed that clear progress has been made in research in the field of climate change impacts on the water cycle, resources and quality over the last few years. There is evidence of ongoing unprecedented changes at rates faster than expected, especially in the Arctic. Climate change and climate impact modelling have considerably improved their capabilities to give short-term projections for a policy-relevant time horizon. These projections now indicate that several socio-economic sectors will be clearly affected, and already need adaptation measures. This will require more research on adaptation strategies, linking physical and ecological impacts and socio-economic aspects. Nevertheless, an important message is that although the projections of changes and impacts still include large uncertainties there is sufficient scientific basis to act, at least in some policy areas.

Different areas were identified at the workshop where research is needed. These can be grouped as follows:

- *Research on the physical and ecological impacts of climate change*

There is a need to improve our knowledge of the complex aspects of the water cycle and aquatic ecosystems, and how these will react to climate change. In particular, it is essential to identify thresholds and points of no return from which no recovery is possible. Research on direct and indirect climatic impacts on the water cycle and ecosystems should continue.

One area in which fast improvement of knowledge is needed is climate-induced change in the elements of the water cycle, the formation of extreme events (floods, droughts, storms, etc.), their magnitude and frequency, as well as their consequences in aquatic ecosystems, such as the destruction of habitats.

As regards droughts, there is also a need to include the increased competition for water as a resource for economic versus ecosystem requirements.

There is a need to further investigate the impact climate change has on biogeochemical cycles of nutrients and toxic substances: to what extent climate change will increase the loads of nutrients and pollutants entering aquatic ecosystems, and thus aggravate eutrophication problems, including increased frequency of algal blooms. Not only the frequency of toxic blooms and increased algal biomass can be the consequences of climate change, the pathways of toxic pollutants (pressures and distribution in the ecosystems) may also change.

- *Research on the socio-economic impacts of climate change*

There is a need for better understanding and quantification of the economic and social impacts of climate change in the different sectors through:

    - the integration of geo- and biophysical models with socio-economic models
    - better understanding and quantification of costs and benefits of impacts in the different sectors
    - better understanding and quantification of the vulnerability and adaptive capacity of receptors to change
    - better understanding of feedbacks and interactions between changes in land use, water cycle, water quality, climate and the socio-economic system.

- *Improvement of models*

    (a) <u>Increased spatial resolution of climate models</u>: regional and local impact studies require the spatial scale of climate models to be reduced to 1-10 km.

    (b) <u>Inclusion of interactions and feedback mechanisms</u>: climate models need to account for interactions and feedbacks between climate, land use and hydrological processes. There is a need for better representation of hydrological processes in land-surface climate models.

    (c) <u>Integration of models</u> is necessary. Assessing the impacts of climate change in different socio-economic sectors calls for the integration of data and methods from a broad range of sources and disciplines and requires climate, hydrological, bio-physical, ecological and socio-economic models to be linked.

- *Monitoring*

The importance of continuing to monitor and increase the available datasets was underlined during the workshop. There is a need for high-quality observations, reference datasets and improved reanalysis of historical data from climate change detection studies, trend analyses, process research, data assimilation, model development and testing. Areas where monitoring was identified as a priority included: records on ice cover decrease, warming of the ocean, sea level rises, pools of migration, biological responses and physical changes. Sufficient funding for this monitoring is essential to provide the basis for scientific progress and policy-relevant results. Greater effort must be made to prioritise the funding of monitoring. Socio-economic data are also necessary to quantify, in monetary terms, the impacts of climate change, the costs and benefits of adaptation strategies, and the vulnerability and adaptive capacity of receptors to change, including in other parts of the world, where climate impacts are likely to be more severe than in Europe. This aspect is extremely relevant in developing countries and less developed countries, where economic resources and strategies to adapt to climate change are scarce.

- *Uncertainty*

There is a need for better understanding and quantification of uncertainty throughout the chain of "emissions → climate → physical impact → ecological impact → socio-economic impact". One possible way could be to use multi-model ensemble approaches that provide the respective uncertainty ranges. Another important challenge is to engage in research on how to communicate uncertainty to decision-makers, by way of cost-benefit analyses and aid to decision-making in the face of these uncertainties.

- *Improvement of the approach adopted in future research*

  (a) In terms of scale - geographical dimension: there is a need for regional and also for global research. It is advisable to approach climate impact problems increasingly on a regional scale. Moreover, it is essential to look at adjacent EU regions, such as Africa, not only from a humanitarian perspective but also as a matter of European security. African societies have little capacity to adapt and will face severe problems, such as insufficient water availability, in terms of both quantity and quality. This may increase pressure of migration to Europe, bringing with it severe problems in terms of security, social impact, environmental damage etc.

  (b) In terms of the sectoral dimension: even if a sectoral approach will improve knowledge on specific issues, a cross-sectoral approach is required to highlight cross-sector interdependency. How to lay a solid basis to explain and reflect on such cross-sectoral interdependency must be integrated in future research.

3 – Policy dimension

The current EU water policies (e.g. Water Framework Directive, WFD) have a planning cycle reaching 10-30 years into the future. Within this timescale, the projected climate change and its impacts on the water cycle and water resources will likely lead to higher environmental, ecological and socio-economic pressures and costs in Europe. To reduce the pressures and minimise the costs of adaptation, decision-makers need guidance from the scientific community in terms of uncertainty ranges for different climate model scenarios at regional level, as well as knowledge on impacts of climate change on the ecosystem baselines, thresholds and points of no return used to identify policy targets.

The scientific community should also improve the communication of areas where all climate models agree and uncertainty is small, such as the robust finding that semi-arid and arid areas of the Mediterranean will become warmer and drier in summer.

Policy-makers have to take decisions on and adapt measures to climate change even if there is uncertainty. This was done, for example, when the specific targets of the European Climate Change Programme (ECCP) II were set. Other examples are given in the three case studies presented at the workshop, which showed that, in spite of all uncertainties, it is possible to initiate and implement adaptation strategies.

Quick and efficient responses are necessary to ensure adequate investment and priority-setting across different sectors, e.g. in land use and spatial planning. This will require a more inter-sectoral and flexible management approach.

One of the main issues mentioned during the workshop was to decide at what level action is required - local, regional, national or EU-wide. Member States (MS) should take appropriate action within their national confines, but it is also necessary to raise the level of awareness among MS of the need for international collaboration to solve larger regional or transboundary problems. The need for a new arena or programme for exchange of experiences and good practices on adaptation across Europe was underlined.

Climate change and the Water Framework Directive
A special challenge for MS is how to handle the impacts of climate change in their implementation of the Water Framework Directive. The following points summarise the workshop discussions on this topic:

- The WFD is an important legal instrument with enough flexibility to allow adaptation to climate change and climate change-related issues. The WFD uses the River Basin District (RBD) as the main unit for the management of River Basins (RBs). WFD-compliant management of River Basins requires the adoption of a cross-sectoral approach (agriculture, land use, water supply and sanitation, urban planning, transport and energy production). The River Basin level is also suitable for coping with extreme events. Therefore, the RB is the unit that can be used to apply climate change adaptation measures.

- Moreover, the WFD already involves economic aspects by putting a price on water use that will affect decisions on water use.

- The WFD encourages stakeholder involvement.

- The WFD might be a tool for climate change adaptation purposes, but a procedure should be identified in the very near future. The WFD provides a framework for considering climate change as one of the pressures. MS should therefore incorporate climate change adaptation measures into their River Basin Management Plans (RBMPs) to ensure that the larger programme of measures is sufficient to achieve the WFD objectives (good status of water bodies). However, MS are not ready to incorporate climate change in the first programme of measures, since this action would require more knowledge on how climate change affects the ecological and chemical thresholds used to identify the ecological target status.

- Climate change should be taken on board within the Common Implementation Strategy (CIS), e.g. as a separate, horizontal activity, and also be linked to existing activities dealing with ecological status assessments (such as intercalibration and monitoring). This will enhance the frame for discussions between MS, and will help to adjust both the target values and the design for monitoring and reporting.
- Access to information: It will be important to consider the availability of information from science results and from policy input.

Important areas for improvement are:

1. Incorporating explicit references to climate change in the WFD and Common Implementation Strategy. Although the principle of “non deterioration” also encompasses climate change, there might be a need for some explicit reference to climate change in the Directive and in its implementation strategy.

2. Increasing the flexibility of the WFD-compliant classification system used by MS to assess ecological status, in particular by adapting baselines and target values to the new conditions imposed by climate change. The relationships between good ecological status and different human pressures should not be regarded as static. The challenge is therefore how to take into account climate change when setting target status objectives. Scientific progress on how climate change affects the pollution loads of water bodies, as well as their baseline and target values, should be quickly assimilated by the river basin authorities as a basis for the much-needed review of their classification systems.

3. The interaction of climate change with other human pressures and their combined impact on water bodies should be handled through the programme of measures. Adaptation and mitigation measures probably need to be more extensive to counteract the combined impacts of human pressures and climate change on European waters. In this context, another challenge is to investigate the interaction of climate change and other human pressures (such as remobilisation and run-off of nutrients and contaminants from soils).

   As ecosystem responses are mostly non-linear, the main emphasis in research, as in the planning of adaptation measures, should be put on ecosystem thresholds, regime shifts and points of no return for aquatic ecosystems. It is incomparably more expensive or even impossible to restore an ecosystem after a major collapse compared to the costs of protective measures ensuring system stability.

4. Coherent multi-sectoral objectives need to be set in order to avoid contradiction with other legal instruments and to enhance synergies. This applies both to the EU level for the different sectors dealing with water, agriculture, energy, transport, nature protection, etc., and to the MS, who are responsible for achieving various objectives across the different sectors. There is also a need to consider coherence between several policies in which water plays a key role. These objectives and the ways of achieving them should be harmonised.

   - *WFD and Flood Directive*:
     - Implementation of the Flood Directive is the right time to take on board climate change adaptation. Flood maps and maps of areas of risk required by the Flood Directive address climate change and can be used to improve RBMPs.
     - There is a need to avoid contradiction between the WFD measures to achieve good water quality and the flood protection measures.

   - *WFD and regional policy*: RBMPs and Regional Development Plans are potential areas for integrating climate change impacts.

   - *WFD and Habitats Directive*: The impact of climate change on habitats has to be taken into account in nature protection policies and also in WFD objectives related to protected areas.

   - *WFD and Renewable Energies Directive and Biofuels*: By 2010, Member States should ensure that a minimum proportion of biofuels and other renewable fuels is placed on their markets. To that effect a reference value for these targets shall be 5.75%, calculated on the basis of energy content, of all petrol and diesel for transport purposes. Therefore, there is a need to investigate how this is going to impact both land use and water, and biodiversity. Further research is needed on the performance and trade-offs for GHG emissions.

Climate change needs to be integrated in all policies. Climate change is already a reality and its impacts need to be considered both internationally and across different sectors, such as water, agriculture, and other economic sectors. More research is needed on the feedback mechanisms between climate change and land cover changes. Local managers need guidelines to help them cope better with climate change impacts. With extreme events becoming more frequent and more disastrous, there is a clear need for adaptation and public awareness. Future challenges need to be anticipated and measures taken at policy level today.

4 – The importance of economics

Four aspects were highlighted:

1. Importance of bringing economists on board: there is a need for closer dialogue between science and economy, to prevent any decisions based on climate predictions from neglecting important socio-economic aspects, and to prevent any decisions based on purely economic and social aspects from neglecting important scientific results.

2. Making an economic case: there is a need to translate climate change impacts into economic terms. The focus should not only be on showing the costs, including timing and discounting, but also on evaluating current and future benefits of mitigation and adaptation, including environmental benefits. Policy-makers should strive to strike a balance between the costs of adaptation measures as incurred today and their potential benefits for the future. The upcoming Green Paper on adaptation should reflect on the benefits of investing in adaptation measures now. It is important to show that investments today will be gains for the future, because if the changes are not done now, the costs will increase in the future. Recent studies have shown that adaptation to climate change (carrying out sectoral changes and capitalising) will cost about 0.3% of GDP. This information might increase the political will to prioritise adaptation measures, and thus avoid higher costs in the future.

3. Climate change is global in its causes and consequences, and the response requires international collective action. Working together is essential to respond to the scale of the challenge. Climate change represents a unique challenge for economics: it is an example of market failure. The economic analysis must be global, and examine the possibility of major, non-marginal change. Analysing climate impacts requires ideas and techniques from most of the important areas of economy.

4. The economic impacts are regionally different and can be either positive or negative, depending on the sector. Regionally different impacts may change competition in different forms of agriculture (crops that will become more, or less, suitable in some regions), or in different energy sources (wind or hydropower energy sources may become more, or less, profitable in particular regions). Economic investigation needs to break away from a global perspective and become more regional.

5 – Bridging needs

The need to improve communication to stakeholders was clearly highlighted, and several suggestions were made regarding stakeholder involvement:

- The increasing damage caused by extreme events may send out a signal to communicate the possible effects of climate change. Experiences with extreme events can make the public more aware of climate change and increase their eagerness to learn more about it and react.

- Communication of the facts of climate change that affect the public must be clear and understandable. An example of this type of good communication is the recent review carried out by John Hanson, which stated that the melting of 50 cubic miles per year in the Arctic is equal in volume to the EU's entire annual consumption of water.

- Communication should be participative, thus ensuring co-ownership between those producing and those using the information.

As regards the *identification of stakeholders*, there is a need to adopt a broader spectrum and to include larger communities, for example, freshwater suppliers to the population and managers of sewage systems. These stakeholders are involved in planning and they will need to know what is going to happen. Particularly important are local decision-makers and operators. They need to follow up issues of monitoring, implementation, revision and future decisions more closely.

In this context, better communication between the scientific community and policy-makers is essential. For this reason the need was raised for the creation of a permanent platform of exchange of information. Climate change and water policy require integration across scientific disciplines, policy areas, socio-economic sectors and stakeholder groups if sustainable adaptation strategies are to be developed.

This executive summary highlights the main discussion points and recommendations to emerge at the workshop. The full proceedings contain abstracts of the different lectures and a summary of the round-table discussions that took place at the end of each session. This workshop and its proceedings were designed as a preparatory step to the Conference on Climate Change and the Water Dimension to be held under the German Presidency in Berlin on 12-14 February 2007.

OPENING SESSION

OPENING SESSION

This session underlined the key drivers of the workshop.

The workshop was organised by three Directorates-General of the European Commission: the Directorate-General for Research, the Directorate-General for Environment and the Joint Research Centre.

This session was opened by the Director-General of the Joint Research Centre, Roland Schenkel. It was followed by presentations from Daniela Jacob from the Max-Planck Institute in Germany, and from representatives from the European Commission, Elisabeth Lipiatou, Head of the Environment and Climate System Unit in the Directorate-General for Research, Peter Gammeltoft, Head of the Protection of Water and Marine Environment Unit in the Directorate-General for Environment, and Frank Raes, Head of the Climate Change Unit in the Institute for Environment and Sustainability.

Overview of climate change projections in Europe

Daniela Jacob,

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Meteorological and hydrological observations demonstrate that during the last decade the climate has changed. As reported by the *Intergovernmental Panel on Climate Change* (IPCC, 2001), a mean increase of temperature by 0.09 K per decade was observed globally from 1951 to 1989. Up to now, 2006, this trend has continued. Europe experienced an extraordinary heat wave in summer 2003, with daily mean temperatures being about 10° warmer than the long term mean. The increase of temperature varies depending on the region and season. If the temperature of the atmosphere increases, it should be assumed that the water cycle is intensified. However, it has not been possible until now to present clear statements on changes in the water cycle as a consequence of climate change.

Global climate models (GCM) have been developed to study the Earths climate system in the past and future, for which assumptions of green house gases are needed. Theses models are mathematical images of the Earth system, in which physical and biogeochemical processes are described numerically to simulate the climate system as realistically as possible. The model quality, however, can only be judge on in comparison with independent observations. Therefore, time periods of the past are simulated and the model results are compared against measurements before the models are used for climate change studies.

Even today global climate models provide information only at a relatively coarse spatial scale. Therefore high resolution regional climate models (RCM) are nested into global calculations to investigate the impact of potential global climate change on specific regions. The results of these investigations depend on both the quality of the global and regional models and the choice of the climate scenario.

In order to achieve information about the probability, e.g. for the intensification of the hydrological cycle over Europe, several models from different European climate research institutes are used, such as it was done in the EU project PRUDENCE (prudence.dmi.dk).

Following the climate change scenario A2 projecting a relatively strong future increase of greenhouse gases until the year 2100 (IPCC, 2001) and a subsequent global mean temperature increase of about 3.5°, numerous simulations were conducted within PRUDENCE. An analysis of their results for different river catchments shows significant differences between the projected changes over northern and central Europe for the time period 2070 – 2100 compared to the current climate (1961-1990). For the Baltic Sea catchment, a precipitation increase of about +10% for the annual mean is projected, with the largest increase of up to +40 % in winter, while a slight reduction of precipitation is calculated for the late summer. Evapotranspiration will increase during the entire year with a maximum increase in winter. These rises in precipitation and evapotranspiration may lead to an increase of river discharge into the Baltic Sea of more than 20% in winter and early spring. Here, the seasonal distribution of discharge is largely influenced by the onset of spring snowmelt.

For the catchments of Rhine, Elbe and Danube, a different change in the water balance components is yielded. While the annual mean precipitation will remain almost unchanged, it will increase in late winter (January-March) and decrease significantly in summer. The evapotranspiration will rise during the entire year, except for the summer, with a maximum increase in winter. These changes lead to a large reduction of 10 to 20% in the annual mean discharge. Especially for the Danube, the projected summer drying has a strong impact on the discharge that is reduced up to 20% throughout the year except for the late winter (February/March) when the increased winter precipitation causes a discharge increase of about 10%. These projected changes in the mean discharge will have significant impacts on water availability and usability in the affected regions.

Under climate change conditions not only the absolute amounts of precipitation may change but also the precipitation intensities, i.e. the amount of precipitation within a certain time period. The simulation of precipitation intensities or extreme precipitation events requires however a considerably higher resolution than the A2 results presented above so that for example the influence of the topographically largely varying Alps on the formation of precipitation over the Rhine catchment could be adequately calculated. High resolution RCM results show that the global warming until 2050 will lead to an increase of high precipitation events over the Alpine part of the Rhine catchment, especially in summer. This climate change signal becomes clearly visible in the Pre-Alps, but a similar trend is seen in the high resolution simulations over large parts of Europe.

An overview over existing regional climate change simulations for Europe will be presented together with results achieved within several EU-funded projects like MERCURE, PRUDENCE and ENSEMBLES.

Reference

(IPCC, 2001). Climate Change 2001. The Scientific Basis, Cambridge Univ. Press, New York, 105 pp.

SESSION I

CLIMATE CHANGE IMPACTS ON THE WATER CYCLE AND RESOURCES – FLOODS AND WATER SCARCITY

Session 1:

Climate change impacts on the water cycle and resources - floods and water scarcity

The session provided key elements on:

- Risk analysis of freshwater availability in future climate change; certainties and uncertainties and areas for improvement
- Analysis of the relationship between climate change and floods in Europe. Some replies to fundamental questions such as:
  - whether climate change is causing floods
  - how to assess future flood risks
  - how to mitigate future flood risks
  - how to improve future flood risk management
- Mechanisms for precipitation and how land use is affecting the different precipitation regimes that lead to increasing droughts in the Mediterranean basin and contribute to floods in Central and Eastern Europe.
- With respect to top drought, scientific results prove that a large amount of water vapour can be transported over deserts without producing rain. This raises two issues:
  - whether past vegetation in these areas could have provided the priming mechanism to trigger precipitation (summer storms) in former times, and
  - whether the Spanish east coast and other Mediterranean areas are now evolving towards a similar situation by removing vegetation and desiccating marsh areas.
- Regarding droughts, there are solutions for restoring the system in southern Europe. Most of them are long-term (15-20 years). Some of them (specify?) could also help to mitigate global climate change and adapt to its long-term effects.
- Characteristics of tropical developing countries: these are mostly dependent on water resources. There is marked irregularity in precipitation patterns and precipitation has a dramatic impact on people's lives in these countries. The characteristics of the water cycle also have a profound impact on human activities (agriculture, public health, food security, etc.). It was admitted that the processes controlling the water cycle over the tropical continents are not well understood.
- Analysis of the vulnerability of the water cycle and water resources to climate change.

Session 1:

Climate change impacts on the water cycle and resources - floods and water scarcity

A risk analysis for world freshwater availability under future climate change

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Our current world is under the threat of severe changes in the climate system, or more broadly, in the global environment system due to anthropogenic intervention to the natural system. The United Nations Framework Convention on Climate Change (UNFCCC) commits nations to avoiding "dangerous" climate change and "allowing ecosystems to adapt naturally", but the concept of "dangerous" climate change ultimately requires a normative decision based on value judgments. It is also not clear how likely are different amounts of climate change to have major impacts on the world's ecosystems? So far, "dangerous climate change" has often been interpreted in terms of critical levels of climate change, or thresholds triggering abrupt climate change events (Parry et al., 1996). However, relatively minor climate changes that have occurred during recent decades have already impacted local ecosystems (Walther et al., 2002), much larger changes are projected for the 21st century (IPCC, 2001).

We quantify the risks of climate-induced changes in runoff as one of key ecosystem processes during the 21st century by forcing the Lund-Potsdam-Jena (LPJ) dynamic global vegetation model (Sitch et al., 2003) with outputs from 16 coupled atmosphere-ocean general circulation models and mapping the proportions of model runs showing exceedance of natural variability in runoff among others. The outputs represent four emission scenarios: "committed" climate change (i.e. atmospheric composition held constant from 2000), and SRES A1B, A2 and B1.

All the climate model runs were initialized for pre-industrial conditions and run up to 2000 with radiative forcing based on observations and then to 2100 under one of the four scenarios. To capture physiological effects of rising CO_2, we provided LPJ with the time series of global mean CO_2 concentrations for the simulation period. Runoff is defined here as the difference between precipitation and evapotranspiration from vegetation and bare soils (controlled in part by biological processes and influenced by CO_2 concentration as well as by climate), and is essentially a proxy for freshwater supply.

Our analysis does not assign probabilities to scenarios, or weights to models. Instead, we consider the distribution of outcomes within three sets of model runs grouped according to the amount of global warming they simulate (global mean surface temperature difference between 2071-2100 and 1961-1990): <2°C (including simulations in which atmospheric composition is held constant, i.e. in which the only climate change is due to greenhouse gases already emitted, 16 runs), 2-3°C (20 runs), and >3°C (16 runs). We define critical change based on the difference between the 2071-2100 and the 1961-1990 means; more precisely when the change in mean exceeds $\pm 1\sigma$ of the interannual variability during 1961-1990, based on climate observations. For an extreme event occurring once every 100 yr, a shift in the mean by 1σ in the direction of the extreme translates into an 10-fold increase in its frequency: The ‘‘100-yr event’’ becomes the ‘‘10-yr event’’. Thus, our analysis focuses on the risk of impacts of changes in extreme events on freshwater availability.

Globally, widespread increases in runoff north of 50°N are shown with probabilities as high as 50% even for 2°C, rising to 70% for 3°C. Other areas with high probability of increased runoff are northwestern South America and tropical Africa. Some regions, however, have a high risk of reduced runoff. Models differ in the sign of projected runoff changes over Amazonia, but for 3°C, the probability of reduction exceeds that of increase. A similar result is found for Central America, the eastern seaboard of North America, and the interior of China. The risk of decreased runoff is more pronounced at higher degrees of warming, in particular for 3°C. West Africa, and the Middle East are also at risk from drought.

Figure 1 shows the risk of runoff changes focussing on Europe, the areas north of 50°N are clearly under risk of severe increases in runoff with probabilities as high as 50% even for <2°C, rising to >70% for >3°C. Southern Europe however has a high risk of reduced runoff, which becomes especially apparent at higher levels of global warming (>3°C). These results are broadly consistent with changes in runoff simulated for different climate models in other studies (Arnell, 2003).

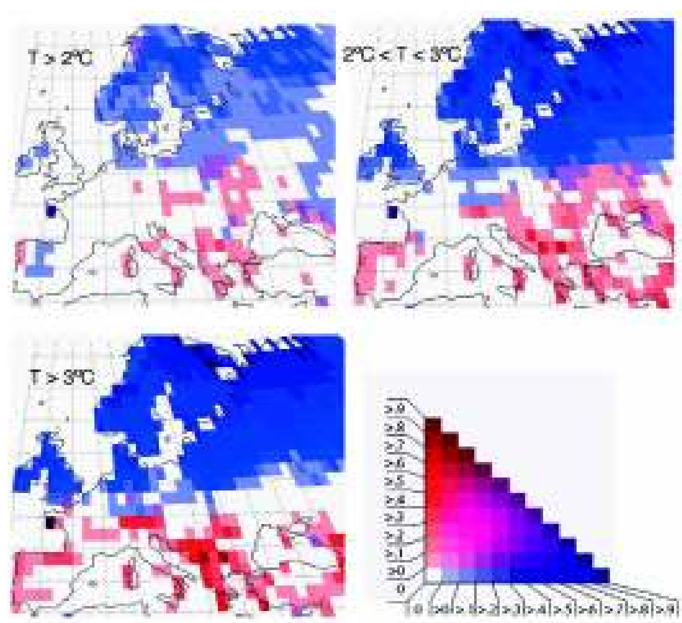

Figure 1. Probability of exceeding critical levels of change in runoff between 1961-1990 and 2071-2100 for three levels of global warming for Europe. Critical change is defined where the change in the mean exceeds one standard deviation of the observed (1961-1990) interannual variability (blue for increase, red for decrease; mixed colours show cases where different runs produce changes in opposite directions, colours are shown only for grid cells with ≥100 mm yr^{-1} runoff in either of the two averaging periods).

This analysis is based on annual runoff values and therefore neglects the seasonality of runoff, however, changes in the seasonality do affect agricultural practices and can lead to major yield losses. Also, we do not take into account either present or future water demand, although clearly, factoring in water demand would give a more meaningful indication of stresses on the water system.

This study clearly cannot provide an unambiguous definition of dangerous climate change, however it may help to inform policy discussions by drawing attention to the steeply increasing risks to ecosystem services such as runoff associated with global climate changes beyond the range to which the climate system is already committed.

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Session 1:

Climate change impacts on the water cycle and resources - floods and water scarcity

Climate change and floods in Europe

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Are floods on the rise?

Floods are the most common natural disaster in Europe. Over the last decades, the costs of floods have exhibited a rapid increase (*Munich Re*, 2005). Part of the observed upward trend in flood damage can be attributed to socio-economic factors, such as increase in population and wealth in flood-prone areas, and to land-use changes, such as urbanisation, deforestation and loss of wetlands and natural floodplain storage (e.g. via dyke construction, river straightening and floodplain sedimentation). Changes in climate may also have played a role. However, the conclusion of a positive contribution of climate change is premature (*Mudelsee et al*., 2003; *Kundzewicz et al*., 2005), partly because of the inherent difficulties and uncertainties in detecting trends in extreme river flows amidst strong natural variability.

Recent advances in climate modelling suggest that climate change will likely play a role in the future. For the coming decades, it is projected that global warming will intensify the hydrological cycle and increase the magnitude and frequency of intense precipitation events in most parts of Europe, especially in the central and northern parts (*Christensen and Christensen*, 2003; *Semmler and Jacob*, 2004). This will likely contribute to an increase in flood hazard triggered by intense rain, particularly the occurrence of flash floods. Flood hazard may also rise during wetter and warmer winters, with increasingly more frequent rain and less frequent snow. On the other hand, ice-jam and early spring snowmelt floods are likely to reduce because of warming (*Kundzewicz et al*., 2006).

Flood risk - its components and drivers

Risk has been developed and used across a wide range of disciplines. As a result, no unique definition of risk exists. Flood risk, typically used as a measure of economic losses from flooding, is defined here as the probability of a flood hazard multiplied by vulnerability and exposure. A schematic representation of flood risk, its components and drivers is presented in Figure 1. Flood hazard is the threatening natural event, including its probability of occurrence and magnitude. Exposure represents the capital, humans and ecological assets exposed to the hazard (typically expressed by statistics on population, socio-economic data on sectorial activities and infrastructure). Vulnerability describes the potential to be harmed or the susceptibility of the receptor to the flood hazard. It is therefore an indication of the measures taken to mitigate the effects of flood events. Thus, flood risk is a potential loss having an uncertain occurrence and size. It is a consequence of hazard, vulnerability and exposure. In practice, exposure and vulnerability are often captured in the assessment of the consequences. Socio-economic drivers, land use and climate affect the components of flood risk in a variety of ways and are often interlinked. This renders it difficult to detangle the effects on flood risk of an individual driver such as climate change.

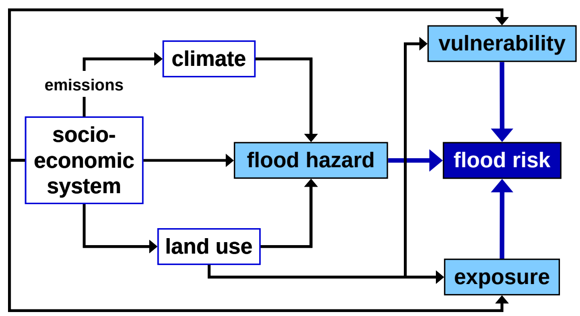

Figure 1. Schematic representation of flood risk, its components and drivers.

Flood hazard assessment

Flood generation is a highly non-linear process that depends on factors such as the intensity, volume and timing of precipitation, antecedent conditions of the river basin (e.g. soil wetness, snow or ice cover), river morphology, land use, and flood control measures (e.g. reservoirs, dykes). Because of the small to meso-scale character of these factors, flood hazard assessment is typically carried out at the catchment scale by means of one-way coupling of climate model output with a hydrological model. In recent years, under the umbrella of several EU projects (e.g. PRUDENCE, ENSEMBLES), a number of regional climate change projections have been developed. Their spatial resolution ranges from 50 to 10 km, approaching the scale that allows capturing fine-scale climatic structures induced by complex topography or land use patterns, which is essential for flood hazard assessment.

Relatively few studies have appeared in the literature that focus on the impacts of climate change on extreme river flows. Among them, there is a geographical preference for catchments located in the UK (e.g. *Kay et al*., 2006), Benelux (e.g. *Booij*, 2005), Germany (e.g. *Shabalova et al*., 2003) and Scandinavia (e.g. *Graham et al*., 2006). Several studies report an increase in flood frequency and intensity, while others show a decreasing trend. The application of different climate scenarios and hydrological models, as well as the basin-specific characteristics make it difficult to compare results of different studies and to draw an overall picture of the effects of climate change on flood hazards at the European scale. To date, only the study of *Lehner et al*. (2006) considered an integrated European assessment of changes in flood hazard due to climate change and changes in water use. Their results are presented in Figure 2 and indicate that regions most prone to a rise in flood hazard are northern to northeastern Europe.

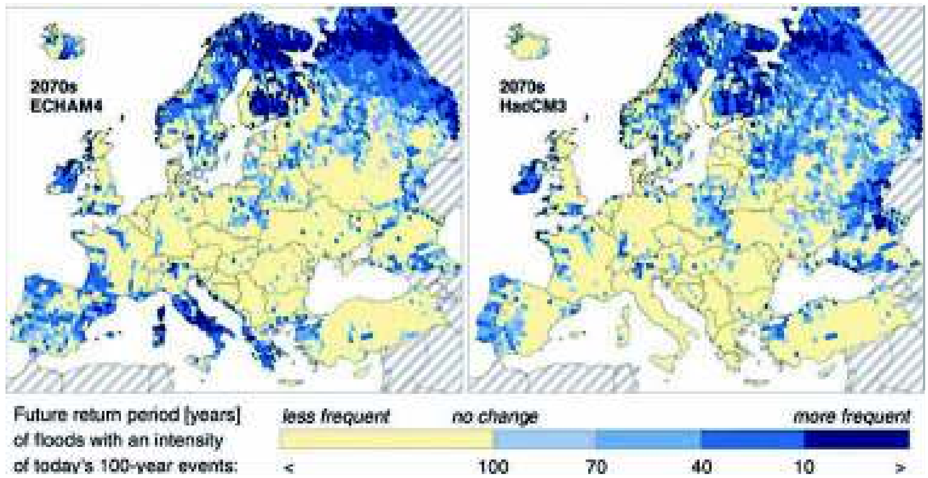

Figure 2. Change in recurrence of 100-year floods, based on comparisons between today's climate and water use (1961-1990) and simulations for the 2020s and 2070s (ECHAM4 and HadCM3 climate models and Baseline-A water use scenario). Values calculated with WaterGAP 2.1. (from Lehner et al., 2006).

Flood risk assessment

Flood risk assessment requires the integration of the physical impact results (inundation extent and depth) with information on flood defences (including probability of failure), land use, and impact (depth-damage functions and population data). Monetary assessments of the impacts of climate change on floods in Europe have been poorly covered. *Hall et al*. (2005) present a national-scale assessment of current and future coastal and river flood risk in England and Wales. Their results indicate an up to 20-fold increase in real terms economic risk by the 2080s for the scenario with the highest economic growth. A study by the Association of British Insurers reports similar findings, with a 15-fold increase in flood risk by 2080 under the high emission scenario (*ABI*, 2005).

At the Institute of Environment and Sustainability of the Joint Research Centre, an integrated methodology is being developed to assess current and future flood risk at the European scale. The framework is presented in Figure 3. Within the PESETA project, the methodology was applied in two pilot catchments. For the Upper Danube, the potential damage of a 100-year flood is estimated to rise by ~40% for the high emission scenario (IPCC-SRES scenario A2) and ~19% for the low emission scenario (B2) by the 2080s. The number of people affected is projected to increase by 242,000 (~11%) for the A2, and 135,000 (~6%) for the B2 scenario. For the Meuse, the potential damage of a 100-year flood is estimated to rise by ~14% for the A2 scenario and ~11% for the B2 scenario. For both scenarios, the estimated increase in number of people affected is approximately 4% (*Feyen et al*., 2006).

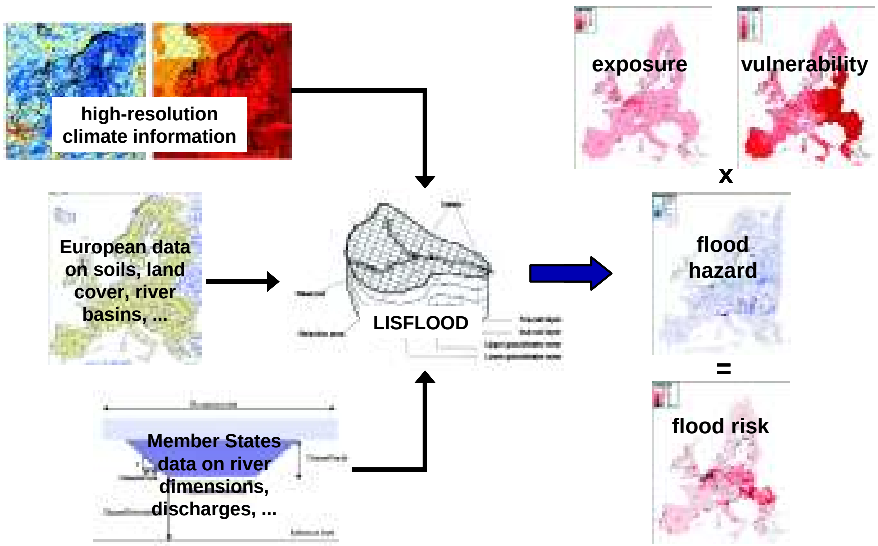

Figure 3. Integrated framework of the IES - JRC for current and future flood risk assessment at the European scale.

Adaptation

In view of climate change, water managers can no longer rely on the assumption of stationarity. Current procedures for designing flood-control infrastructures have to be revised and consider the projected changes in extreme river flows, as well as the existing uncertainties. For example, *Hennegriff et al*. (2006) calculate climate change factors to adjust currently valid peak design values for catchments in Baden-Württemberg. In recent years, flood management policy has shifted from defensive action towards management of risk and enhancing societies' ability to live with floods via increased use of non-structural flood protection measures. Spatial planning, including regulation of floodplain development and relocation, can consider more 'room for rivers' (e.g. *Klijn*, 2004). Watershed management (soil conservation, afforestation) can be directed to enhance retention and reduce direct runoff. Increasing warning times in flood forecasting can considerably mitigate damages. To this end, the European Flood Alert System (EFAS) was developed (*de Roo and Thielen*, 2004). With a lead-time of 10 days, it complements national warning systems, which typically have lead-times up to 2-3 days. EFAS also produces flood alerts based on an ensemble of probabilistic weather forecasts produced by ECMWF, hereby anticipating a wider range of weather developments. Non-structural measures, which do not involve large structural components, can be rated as more flexible, less committing and more sustainable than hard measures. Yet, the latter may be indispensable in certain circumstances (*Kundzewicz*, 2002). Water managers are thus faced with the challenge to design a site-specific mix of both types of measures, which may be altered or are robust to changing conditions.

Research challenges

A strong evidence base is important in decision making. Proper assessment of changes in flood risk and cost-benefit analyses of adaptation options requires major research advances in the fields of climatology, hydrology, land use planning, socio-economy and multi-objective decision making under uncertainty. This need will have to be met via national research and the EC Framework Programmes (FP). EC-funded research has increasingly tackled flood-related issues since the early 1980s and research on flood risk and climate change will continue in FP7. There is a need for sustained, high-quality climate and hydrological observations, reference data sets and improved reanalyses of historical data for climate change detection studies, trend analyses, process research, data assimilation, model development and testing (e.g. WATCH). It is necessary to advance scientific understanding of the climate mechanisms that trigger or alter the probabilities of extreme events, and to improve the capabilities of high-resolution regional climate models (e.g. CECILIA) to simulate and predict extreme events at the regional and local scale. Interaction between land use and climate variability and change is poorly understood and will require the development of new models linking geophysics of climate with the socio-economic drivers of land use. Early warning systems need to be improved (e.g. EFAS, PREVIEW), in particular for flash floods (e.g. FLOODsite). Improvements are also necessary in quantifying the damages of floods (e.g. depth damage functions) and the costs/benefits of structural and non-structural paths for adapting (e.g. ADAM), as well as in the monetary evaluation of environmental benefits. There is a need for the formal treatment of uncertainty throughout the chain of emissions → climate → extreme flow → inundation → damage, through multi-model ensemble approaches that probe the respective uncertainty spaces. Research on flood risk mapping and flood risk management in the face of these uncertainties is an important challenge (e.g. FLOODsite).

European Dimension

Besides directing, stimulating and consolidating (e.g. CRUE network) research in the fields of floods and climate change, the EC has recently stepped up the effort to reduce and manage the risk of floods in Europe through the advent of a European Action programme on flood risk management. It promotes the exchange of information, knowledge and best practices (e.g. projects like FLOODsite, information exchange circles like EXCIFF and EXCIMAP) and the increasing of awareness. It proposes to make optimal use of EU funding tools for different aspects of flood risk management, for example, via Structural Funds, the LIFE Financial Instrument for the Environment and the EU Solidarity Fund. It also introduces a legal document in the form of a Floods Directive (CEC, 2006). The latter requires that flood risk maps and flood risk management plans be drawn up for areas susceptible to floods, in which possible effects of climate change need to be explicitly considered. The Directive is strongly linked with the Water Framework Directive. The working unit is the river basin, which requires cross-border cooperation in basins shared between Members States (e.g. via International river commissions). Member States have to determine the level of protection and appropriate measures applying the principle of solidarity, not passing problems to up- or downstream regions. Even though transferability of best practices is limited because of location-specific characteristics, the exchange of information by practitioners in different basins is valuable, not least since such pressures as climate and land use change are common to most basins and present similar challenges for flood risk management. In addition, EU and national policies on agriculture, spatial planning, transport and emissions have to be directed towards mitigating flood risk.

Conclusions

Finally, climate and socio-economic changes will likely increase flood risk in large parts of Europe. This poses new challenges to researchers, water managers and policy makers at the European, national, regional and local scales. In order to make rapid progress in flood risk management it will be necessary to integrate data and methods from a broad range of sources and disciplines, which consider possible climate, land-use, and socio-economic changes, as well as water management strategies, in a coherent and consistent way. Only in this way sustainable flood risk management strategies robust or adaptable to changes can be designed.

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Session 1:

Climate change impacts on the water cycle and resources - floods and water scarcity

Climate change and drought: The role of critical thresholds and feedbacks

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An issue in climate is feedbacks. "Predictions of global atmospheric models are highly sensitive to prescribed large-scale changes in vegetation cover", and "although available studies illustrate the potential effects of massive vegetation changes on the climate system, they can hardly be validated" (Claussen 2001). Nevertheless, the fact that the Western Mediterranean Basin (WMB) is a deep sea surrounded by mountains in the subtropical latitudes makes it an ideal testground for checking whether or not vegetation is a passive component of climate, for determining its role in drought and desertification, and for investigating other questions related to feedbacks in climate studies.

Around the Mediterranean, deserts and desert-like conditions are found in close proximity to a warm sea and, thus, to a marine airmass with a high moisture content, e.g., the coasts of Algiers, Tunisia, Libya, and Almeria in Southeastern Spain. These regions were covered with vegetation in historical times, e.g., during the Roman Empire (Bölle 2003a). In Almeria, dense oak forests covering the mountains were cut down to fuel mines just 150 yr ago (Charco 2002). The question is: did these areas run a feedback cycle towards drought and desertification as a consequence of removing the forests and desiccating the coastal marshes? The experimental data and modelling results from several European research projects suggest that this could be the case.

One result of these projects was the disaggregation of precipitation componentes from: (1) summer storms driven by seabreezes, (2) "classic" Atlantic frontal precipitation and (3) Mediterranean cyclogenesis. All of these, it should be strongly emphasised, respond differently to known climatic indexes, e.g., the NAO (Millán et al. 2005b). Other results show that the hydrological system in the WMB is very sensitive to land-use changes. For example, consider the airmass in a seabreeze. As it moves inland its water vapour content increases by evaporation from the surface at the same time that its potential temperature also rises by sensible heating from the surface. The balance between the heat gained and the moisture accumulated determines the airmass' Cloud Condensation Level (CCL), which will become a critical threshold if forced to rise above the coastal mountains by lack of moisture. This inhibits the development of summer storms (Millán et al., 2005a) and tips the local climate towards increasing drought.

The latter situation now prevails in the WMB where the seabreezes, their return flows aloft, and their compensatory subsidences over the sea become self-organized in closed vertical recirculations (Figure 1) that extend to the whole basin from April to early October for periods lasting 3 to 10 days (Millán et al., 1997; Gangoiti et al., 2001). This situation affects the coasts of Northern Africa, the Iberian peninsula, southern France and southern Italy, and suggests that land use perturbations accumulated over historical time (Bölle 2003b), and accelerated in the last 30 years, may have induced changes from an open monsoon-type rain regime in the past, with frequent summer storms over the coastal mountains, to one now dominated by closed vertical recirculations and fewer storms. In the current situation the non-precipitated water vapour then follows the return flows of the breezes aloft and accumulates over the sea to heights reaching over 5000 m.

Thus, in contrast with regions dominated by advection, pollutants and water vapour can accumulate over the western Mediterranean sea in layers piled over the sea. And, without requiring the high evaporation rates of more tropical latitudes, these mechanisms can generate a very large, polluted, moist, and potentially unstable airmass after a few days (Figures 2b, 3, 4a). Finally, the accumulated airmass can be uplifted by a transitory depression, or a trough of cold air aloft, enabling the cycle to start anew. The uplifted airmass can then feed onto a **V**b depression track (Figure 4b) and contribute to intense summer precipitations in Central Europe (Ulbrich et al., 2003). Alternatively, this airmass can be vented along the southern Atlas corridor towards the Atlantic (Figure 5).

Moreover, perturbations to the hydrological cycle in any part of the basin can propagate to the whole Mediterranean basin and adjacent European regions and, ultimately, to the global climate system, through other linked mechanisms: (1) increasing Mediterranean cyclogenesis in autumn (Pastor et al. 2001) through cumulative (greenhouse) heating of the sea caused by the water vapour and ozone accumulated over the sea, (2) exporting "en masse" the accumulated moisture to other regions after each 3-10 day accumulation-recirculation periods (Ulbrich et al. 2003; Gangoiti et al. 2006) and, as a result, (3) changing the evaporation-precipitation balance over the Mediterranean, which increases its salinity and drives the Atlantic-Mediterranean salinity valve (Kemp-Shellnhuber 2005).

Finally, Figure 6 presents a hypothetical framework linking Western Mediterranean Basin (WMB)- specific atmospheric-oceanic processes, and their possible feedbacks, to effects at the hemispheric (Ulbrich et al. 2003) and global scales (Hamelin 1989; Savoie et al. 1992; 2002; Prospero and Lamb 2003, Kemp-Shellnhuber 2005; Gangoiti et al. 2006). The available results and data indicate that these processes are already operating, and suggest that fundamental changes, and long-term perturbations to the European water-cycle, are taking place right now. The questions raised are fundamental for European Union water policies in Southern Europe and neighbouring regions, especially since feedback processes on the hydrological cycle cannot be properly simulated in the Global Climate models used to assess future water scenarios for Europe, or for other regions still dominated by monsoon-type precipitations.

Acknowledgements: The MODIS images used in this study were acquired using the GES-DISC Interactive Online Visualization and Analysis Infrastructure (Giovanni) as part of NASA Goddard Earth Sciences (GES) "Data and Information Services Center (DISC)". The author thanks Prof. Lucio Alonso of UPV-EHU (Bilbao) for preparing the averages shown.

- The first experimental data used for this work were obtained during the European Commission Campaigns on Remote Sensing of Air Pollution in: **LACQ** (France, 1975), **TURBIGO** (Po Valley, Italy, in 1979) and **FOS-BERRE** (Marseille, France, 1983). Additional experimental and modelling results come from the European Commission research projects: **MECAPIP** (1988-1991), **RECAPMA** (1990-1992), **SECAP** (1992-1995), **T-TRAPEM** (1992-1995), **MEDCAPHOTTRACE** (1993-1995), **VOTALP I** (1995-1998), **VOTALP II** (1995-1998), **BEMA I** (1993-1995), and **BEMA II** (Phase II/

1998-2000), **MEDEFLU** (1998-2000), **RECAB** (2000-2003), **ADIOS** (2000-2003), **CARBOMONT** (2001-2004), and **FUMAPEX** (2001-2005).

This work is dedicated to the memory of Dr. Heinrich (Heinz) Ott (†2004), for his initial support of this research in 1985 and for his 1993 request, to explain the loss of summer storms around the Mediterranean, and Dr. Anver Ghazi (†2005), for his continued encouragement and support of this line of research.

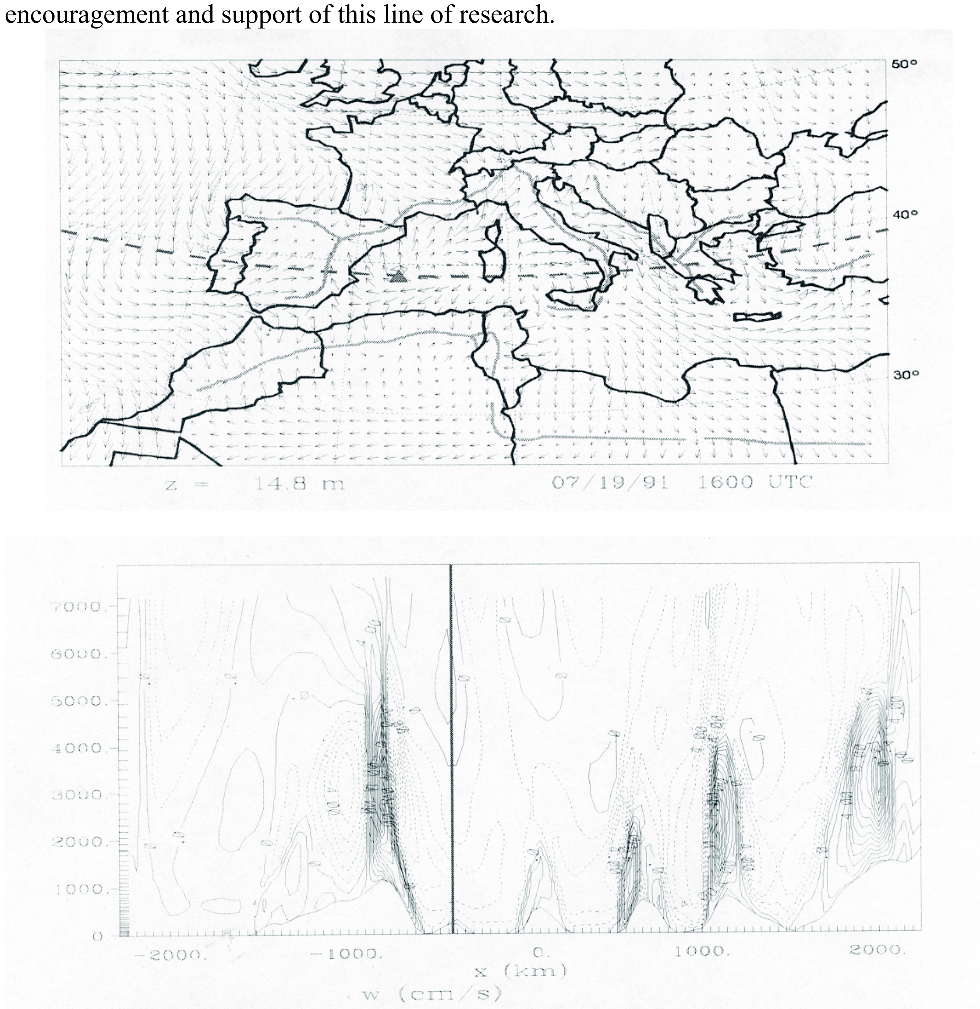
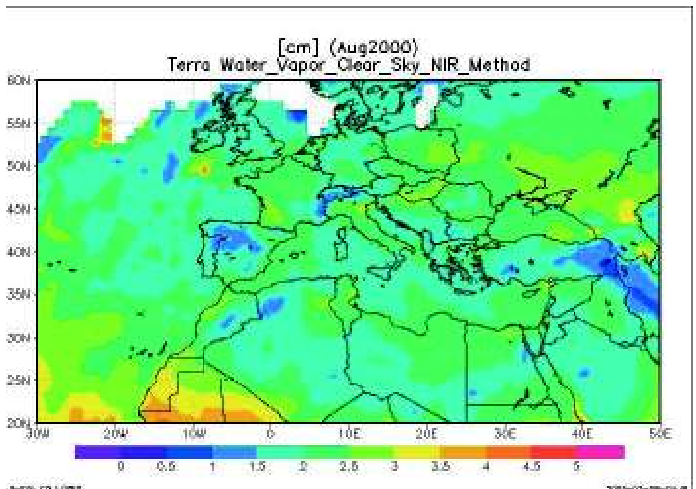
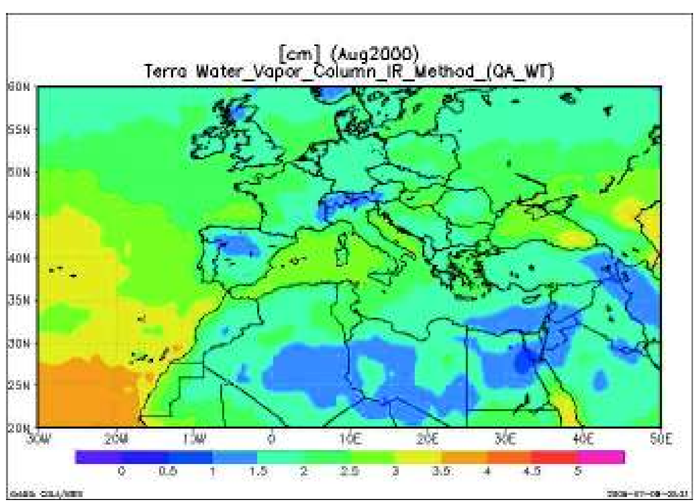


Figure 1. Simulated wind field over the Mediterranean at 16:00 UTC on 19 July 1991, corresponding to a RECAPMA instrumented flight on the same day (15:57 UTC to 16:39 UTC) over the point marked by a red triangle and the vertical line just south of Majorca. **Top graph**: The winds at 14.8 m above the surface emerge from the centre of the western basin and increase in speed while flowing anticyclonically (clockwise) towards the convergence lines located over the mountain ranges surrounding the basin (in orange). **Bottom graph**: The vertical component of the wind speed along the 39.5 North Parallel (dotted blue line in the upper graph) shows deep orographic/convective injections over Eastern Spain and, following to the right, over Sardinia and the west-facing coasts of Italy, Greece and Turkey. Continuity requires compensatory subsidence over the sea to replace the surface air moving

towards the coasts, and thus the airmass over the sea sinks (dotted lines). These processes generate a vertical recirculation that piles up layers of pollutants (and water vapour) over the sea to more than 5000 m high. Available measurements suggest that 1/4 to 1/3 of the layers accumulated over the sea during the previous day(s) are recirculated each day. The modelled sinking speeds, however, are much lower than those measured experimentally during the instrumented flight (Millán et al., 2002). The specific structure of the winds is also conditioned by the orientation of the surface with respect to the sun, which at this time of day is 60° West. The time lag required for the circulations to develop and their inertia are also significant, e.g., at this time, upward motions still remain over the west-facing coast of Turkey but are barely developed over Portugal.



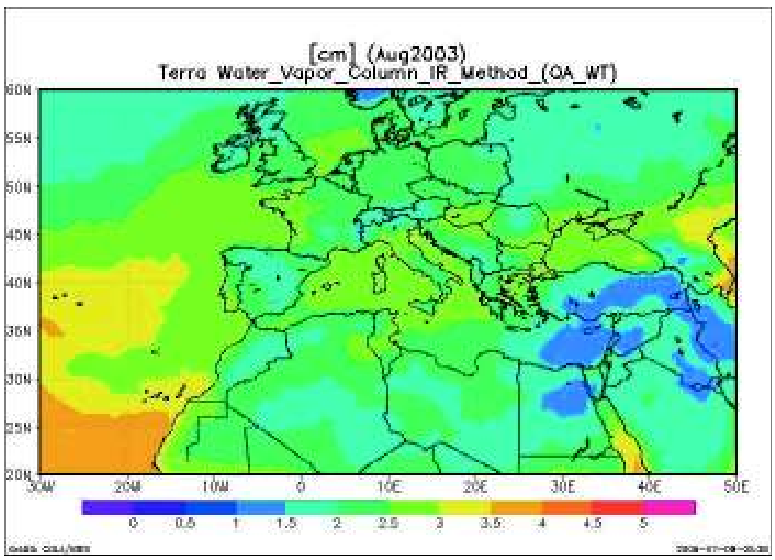
(a) Day



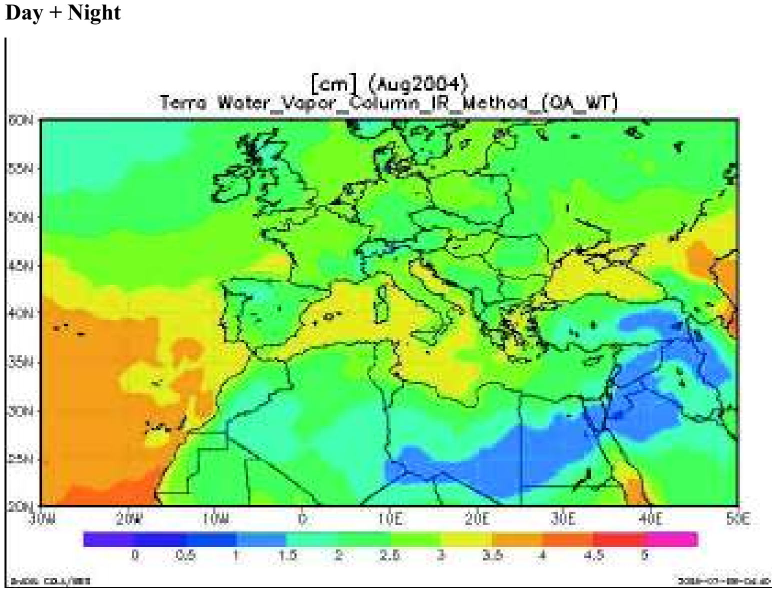
(b) Day + Night

Figure 2. Averages of the NASA MODIS-Terra measurements (King et al. 2003) for August 2000. The water vapour is considered as a tracer of opportunity of the airmasses recirculated by the coastal wind system in the Western Mediterranean Basin. **(a):** The Day product derived from the morning pass at 10:30 UTC emphasises the areas where the satellite looks

down the deep orographic-convection developing at the seabreeze fronts over the mountains surrounding the basin, and over desert areas of northern Africa (Figure 1). **(b):** The Day + Night product shows the average of the satellite measurements at 10:30 UTC plus 22:30 UTC, and highlights the areas over which water vapour accumulation occurs, i.e., the WMB, the Adriatic and the Black seas. Accumulation is weaker over the eastern basin, in spite of higher sea surface temperatures and more evaporation, because the atmospheric flows are dominated by advection (Millán et al., 1997). These MODIS products yield the water vapour signal only and eliminate the data in pixels where condensation is detected (cloud masking). This explains some of the low water vapour column values observed over regions where storms develop frequently on summer days (e.g., Alps, Apennines and Atlantic Mid-Atlas in Morocco).

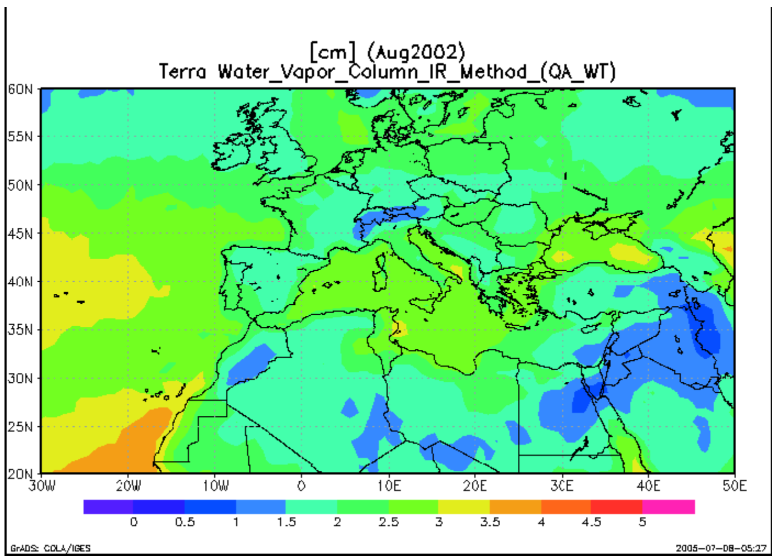


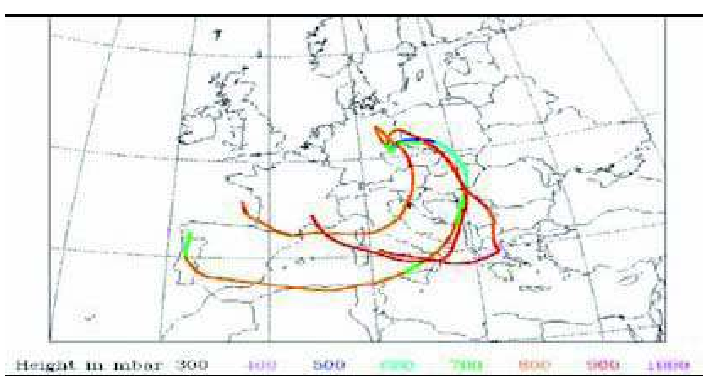
Day + Night



Day + Night

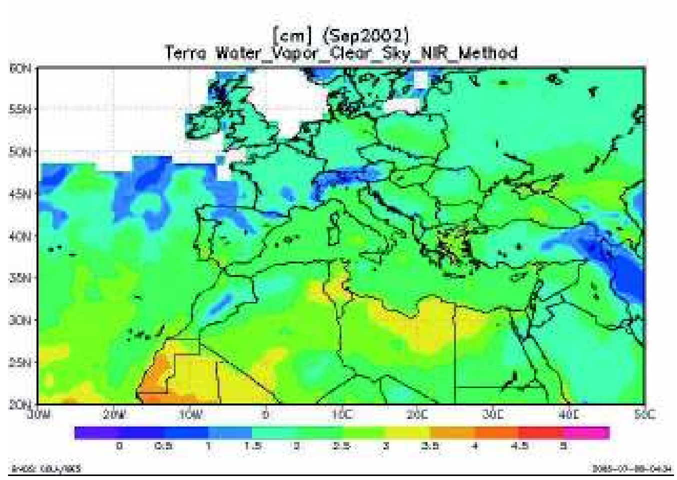
Figure 3. Monthly averages of the MODIS Day + Night product for August 2003 and 2004. Together with the equivalent products for August 2000 (in Figure 1b) and August 2002 (in Figure 4a), these graphs illustrate the evolution of the average water vapour accumulated over the Mediterranean Basin by the coastal circulations in August for these years. They emphasise the "closed" nature of the coastal circulations at this time, with the result that water vapour accumulates over the sea instead of precipitating over the coastal mountain ranges.



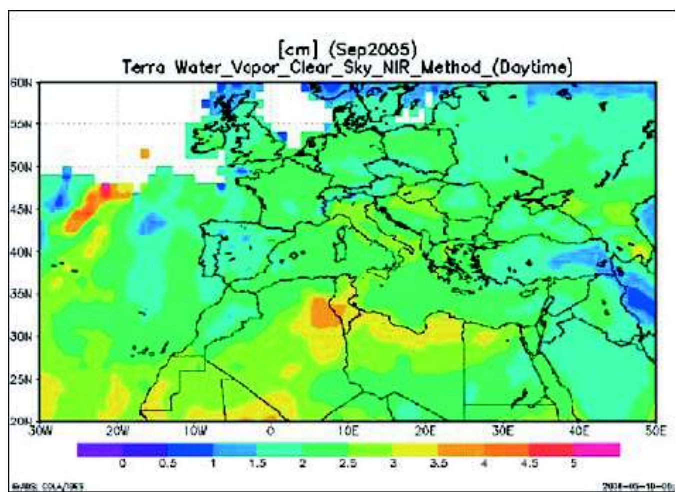


(a) Day + Night

Figure 4. Left. MODIS Day + Night product averaged for August 2002. This value shows the average water vapour accumulated in August 2002 over the western Mediterranean and available for advection to other regions. The graphs at right from Ulbrich et al. (2003) show the back trajectories (type **Vb**) that fed torrential rains in Germany and the Czech Republic on 11-13 August, 2002. These figures illustrate the evident interconnection between processes from the local to the regional scale in Southern Europe and, possibly, further to the global scale.



(a) Day



(b) Day

Figure 5. Monthly averages of the MODIS Terra Day product for September 2002, and for September 2005. These graphs support previous working hypotheses on the transport of Mediterranean airmasses along the southern Atlas corridor as one of the outputs of the basin during the vertical recirculation/accumulation periods (Millán et al., 1997). They illustrate how much water vapour, together with air pollutants, can be transported from the Mediterranean sea to the Atlantic ocean over the Sahara desert. This advected moisture could help in the formation of shallow clouds in any up-slope winds developing on the south-facing slopes of the Atlas mountains. Moreover, these shallow clouds can provide the right environment for heterogeneous reactions involving Saharan dust and pollutants from the Mediterranean area. With respect to drought, the figures also illustrate how a large amount of water vapour (i.e., nearly 3 precipitable cm) can be transported over desert areas without producing rain. This raises two questions: whether past vegetation in these areas could have provided the additional moisture required to trigger precipitation (late summer storms) in former times, and whether the Spanish east coast and other Mediterranean areas are now evolving towards a similar situation by removing vegetation and dessiccating marshes,

thereby diminishing the sources of additional moisture required to keep the Cloud Condensation Levels below their critical thresholds.

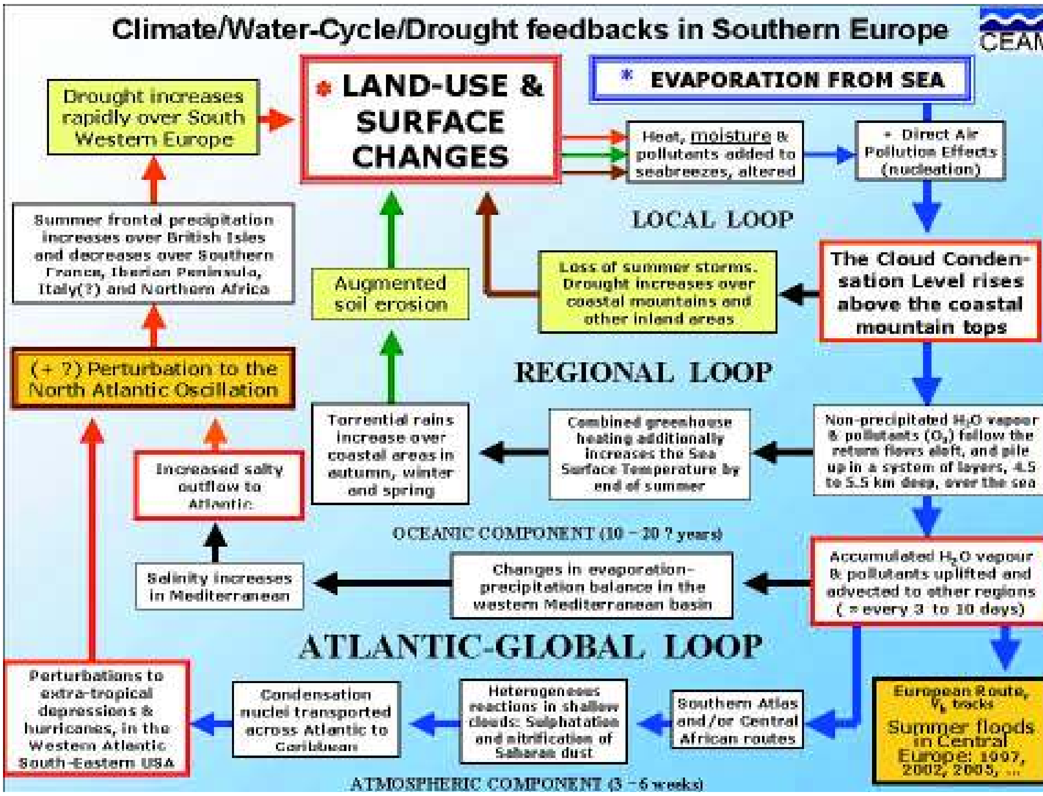


Figure 6. Feedback loops between land-use perturbations in the Western Mediterranean basin and the climatichydrological system from the local through the regional to the global scales. The first, local, loop involves the seabreezes and the storms that develop in the afternoon over the coastal mountain ranges. It has a diurnal cycle and a scale of the order of 100 km to 300 km for the surface inflow and the return flows aloft, and it can be repeated for 3 to 10 consecutive days within the western Mediterranean Basin. The regional loop influences the evolution of the Sea Surface Temperature in the western basin during the summer. This warm(er) water then feeds torrential rains in the autumn, and more recently also in winter and spring. Finally, the Atlantic-global loop has two components which can affect the North Atlantic Oscillation (NAO): the output of saltier water to the Atlantic and the possible perturbations to the extra-tropical depressions and hurricanes in the Gulf of Mexico generated by changing the characteristics of the Saharan dust transported across the Atlantic. In this figure the path of the water vapour is marked by dark blue arrows, the directly related effects by black arrows, and the indirect effects by other colours. Critical thresholds are squared in red.

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Session 1:

Climate change impacts on the water cycle and resources - floods and water scarcity

Climate change impacts on water resources in developing countries

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Tropical climates are characterized by a high variability of their water cycle during the year. The biology, hydrology and more generally the evolution of the environment are controlled by the succession of dry and wet seasons. The sharp contrast between the dry and wet seasons also affects human activities. Agricultural production is controlled by the quality of the rainy season. Water resources need to be managed in such a way that no scarcity occurs during the dray season. Finally many diseases are also controlled by the presence of absence of rain and thus the variability of the water cycle also affect public health. Developing countries have their economies, infrastructures and social activities tailored to the characteristics of the water cycle. Thus any change to the characteristics of the rainy season (its onset, length, intensity or frequency of break periods) will challenge their capabilities to adapt.

It is accepted that climate change will increase the intensity of rainfall events in the tropics. But there is no consensus in the community on the on changes in the onset, length and inter-seasonal variability of the rainy season. There are thus some fundamental gaps in our ability to predict the changes which can be expected in the water cycle of the tropical continents for an increase in greenhouse gases. The climate research community can not today provide predictions with any degree of confidence to developing countries in the tropical region. This in turn does not allow these countries to study their vulnerability to climate change or develop mitigation strategies.

It is the aim of the African Monsoon Multidisciplinary Analysis (AMMA) project to try and make progress on these issues together with scientists of West African countries. Based on a French initiative, AMMA was built by an international scientific group and is currently funded by a large number of agencies, especially from France, the United Kingdom, the United States and Africa. It has been the beneficiary of a major financial contribution from the European Community's Sixth Framework Research Program. AMMA will enhance our knowledge of the physical, chemical and biological processes of the African monsoon with the aim to improve forecasts at time scales from synoptic to inter-annual and increase our confidence in climate change predictions. At the same time AMMA will study the vulnerability to climate variability of the land-productivity, water resource management and public health in the region. The strong interactions between the geophysical sciences and the human dimension taking place within AMMA should enable the community to propose adaptation strategies to a changing climate which take advantage of the latest progress in climate modeling and knowledge on the dependence of African societies on environmental conditions.

Because of the complexity of the tropical climate and the strong dependence of developing countries on environmental condition, it is believed that only truly multidisciplinary research can try and offer strategies which will allow for a sustainable development in a changing climate.

Session 1:

Climate change impacts on the water cycle and resources - floods and water scarcity

Climate change impacts on global water cycle and implications for water management in Europe

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Changes in the hydrological cycle induced by global warming may affect society more than any other changes, especially with regard to flood and drought risks, changing water availability and water quality. Increasing levels of greenhouse gases are expected to significantly affect the global water cycle leading to large changes of rainfall. Unlike temperature, however, precipitation is strongly determined by the detail of the atmospheric circulations and it has proved difficult to reach a consensus on how the patterns of rainfall will change in space and time. The details of how catchments respond will depend on both the regional climate change and the characteristics of the catchments. The climate system is a global, coupled system, thus tele-connections link seasonal and inter-annual climate variability between regions (often associated with ocean anomalies, such as El Niño or the North Atlantic Oscillation). It is therefore important to consider the water cycle globally.
To date, the projection of potential impacts of climate change on the hydrological cycle has relied on projections from global, and nested, regional climate models (GCMs and RCMs). In these models hydrological processes are currently only crudely represented. Thus, future changes in some components, such as precipitation, evaporation, runoff, and precipitable water content can be captured in only a general fashion, i.e. for large areas and basins. Detailed changes, in the regional components of the hydrological cycle, such as groundwater, snowmelt, permafrost and wetlands, are poorly resolved. In addition, several anthropogenic influences on the hydrological cycle are generally not considered within current climate models, such as irrigation, large water storage & regulation facilities like dams and agricultural land use changes and management. This limited physical representation of the hydrological cycle precludes the realistic simulation of all of its components in full detail in space and time. As a result, the current practice of assessing the impacts on water resources involves, in most of the cases, a one-way linking of the outputs from the climate models to 'off-line' local hydrological models. This causes many inconsistencies in both scales (of time and space) and process descriptions; the impacts of the interactions and feedbacks between the components are also lost. There is therefore a need to develop a new conceptual and modelling framework which would connect the climate, hydrological and water resources assessment models in a consistent way, to consolidate this framework with the observed patterns of the hydrological and water resources system in the past, and finally to provide a comprehensive assessment of the current and future global water cycle and water resources vulnerability.

The presentation will cover the hydrological and climate aspects of the present and future global water cycle, and related water resources status, by explicitly addressing:

- the current global water cycle, especially causal chains leading to observable changes in droughts and floods,

- how the global water cycle and the extremes may respond to future drivers of global change,
- feedbacks in the coupled system as they affect the global water cycle,
- the uncertainties in the predictions of coupled climate-hydrological- land use models,
- the future vulnerability of water as a resource, and in relation to water/climate extremes related risks.

SESSION II

CLIMATE CHANGE IMPACTS ON WATER QUALITY - NUTRIENTS, ORGANIC CONTENT, ECOLOGICAL STATUS AND BIODIVERSITY

Session 2:

Climate change impacts on water quality – nutrients, organic content, toxic compounds, ecological status and biodiversity

The session provided key elements on the following issues:

- For contaminants, current knowledge is sufficient to state that feedbacks between climate change and POPs exist and are significant. Mobilisation of POPs from soil and sediment to air, water and biota is a consequence of higher temperatures and increased run-off.
- The clear impact of climate change on biodiversity is already apparent among Arctic and Alpine species, and critical temperature thresholds have been shown for sea grass meadows (*Posidonia*) and corals (29°C).
- Increased nutrient input into aquatic ecosystems, due to a combination of higher temperatures and rainfall and changes in land use, aggravates oxygen depletion in deep waters and harmful algal blooms in surface waters. This may prevent restoration of water bodies to target status, unless additional measures are taken to further reduce nutrient run-off.
- Sea level rises and more frequent storm events increase the erosion of salt marshes.
- Climate change reduces freshwater acidification due to increased alkalinity generation and reduced intensity of spring melt episodes. However, in coastal areas, recovery from acidification may be frustrated by increased storm frequency and concurring sea salt episodes.

The session revealed the following needs for future research:

1. Identification of tipping points or thresholds for aquatic ecosystem responses along pressure gradients and how climate change affects them. These natural thresholds are essential for setting and achieving policy targets, such as the WFD's ecological target status for water bodies.
2. Carbon sinks and sources in shelf and coastal seas and their feedback on climate.
3. Combined effect of elevated temperature and reduced pH on marine food webs.
4. Biogeochemical linkages between terrestrial and aquatic ecosystems.
5. Feedback mechanisms between land cover changes and climate changes.
6. Interactions and feedbacks between climate, chemicals and ecosystem functioning.
7. Assessment methodologies and prediction models for aquatic ecosystems in the context of global change and drifting baselines.
8. Development of a new generation of models to predict aquatic ecosystem responses to multiple pressures, including hysteresis and time lags.
9. High-density monitoring is necessary for data generation to support future research and management.

Session 2:

Climate change impacts on water quality – nutrients, organic content, toxic compounds, ecological status and biodiversity

Sensitivity of freshwater ecosystems for climate change impacts

Dr. Thorsten Blenckner

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Climatic variation and change affect the dynamics of organisms and ecosystem processes. Many studies in the past have analyzed and discussed various climate-driven effects on different variables of freshwater ecosystems. Comprehensive investigations of ecosystem responses to climatic variability and change go beyond collecting facts or observations to include the process of identifying and testing generalizations or theories that explain those facts as instances of a general pattern. Rigorous testing of the sensitivity of ecosystems to climatic change (or global change in general) requires appropriate data. Climatic effects on freshwaters can only be detected when long-term data (at least 20 years), such as proxy data or adequate long-term monitoring data are available. Long-term observations across many years define the range of natural variability of ecological systems and provide a baseline from which to assess whether a system has changed significantly or crossed a threshold, i.e. resulting in a different ecosystem state. In the optimal case, long-term data are gathered with the same sampling and analytical methods. In practice that is seldom the case and this lack of consistency can have a negative influence on the quality of the data. Another possible concern arising from the use of long-term data is that human impacts, besides climate change, are not constant over time. For example, in the past 40-50 years, many lakes, particularly in Europe and the US, have been subjected to anthropogenically increased nutrient supply. This supply decreased again in the late 1980s or early 1990s. While improvements in wastewater treatment over the last decades have reduced inputs of nutrients from point sources, the increase in nutrients from diffuse sources is still a major problem and for many lakes remains the predominant concern. Also other anthropogenic changes (e.g. land-use changes, toxic pollution, hydrological modifications, overfishing) can complicate the separation of the various influences on long-term data sets. The three main objectives of this presentation are: first to present a conceptual approach which helps in understanding individual ecosystem responses to climatic change and variability, and second, to apply the state-of-the-art knowledge to this conceptual framework. Finally, the resulting sensitivity of freshwater is further explored and future challenges for research and political decisions are presented.

In this overview, a conceptual model will be explained to illustrate why freshwater ecosystem respond individually to climate change and variability. The model consists of two main components, a so-called *Landscape Filter* comprising the features of geographical position, catchment characteristics and lake morphology, and a so-called *Internal Filter*, comprising the features of environmental history and biotic/abiotic interactions. The application of this conceptual model on state-of-the-art knowledge illustrates the strength in this encompassing perspective. In particular, several examples based on time-series analysis and modeling, of climate-driven changes on water temperature, ice cover period, bottom oxygen concentration, nutrient concentration, water colour and the risk of phytoplankton blooms such as toxic cyanobacteria (blue-green algae) blooms in different freshwater ecosystems will be shown.

Based on this review, it became obvious that freshwater systems do not respond to change in a smooth way, rather a stressed ecosystem can suddenly shift from a seemingly steady state that is difficult to reverse. As a result, freshwater resources are becoming increasingly complex to manage. Therefore, it is suggested that the following challenges remain to be met to improve the understanding of ecosystem sensitivity and, therefore, ecosystem management: (1) The inclusion quantitative studies of thresholds and points-of no-return which can change the water quality and ecosystem state, e.g. the change of a clear water lake into a turbid water lake (2) Construction of general ecosystem models to simulate the sensitivity of biogeochemical processes for a large number of lakes, rather than for individual systems. (3) An intensification of monitoring and data availability, including in particular monitoring on short time scales, in order to increase the understanding of how the variability of ecosystem variables can lead to changes in the ecosystem state and to improve the prediction of the variability of water quality measures. (4) Inclusion of biogeochemical linkages between terrestrial and aquatic ecosystems into model and statistical approaches to assess the effect of external stressors such as land-use changes. Only the combination of the above named different approaches will lead to an understanding and improvement of management of lakes exhibiting multiple stressors in a changing future.

At the moment, many scientists focus their work on data analysis and develop models to predict nonlinear processes and feedbacks to reduce the uncertainty water quality and ecosystem models of for example climate-driven changes on water quality under a future climate. However, at the same time decision makers need to know the answers, e.g. the risk of severe water quality problems such as cyanobacterial blooms in the near future, well before scientists have finally resolved and quantified the uncertainties in the data and model structure. These interest groups are, therefore, forced to base their decisions of high political importance on partly uncertain system information. Before models reach a higher certainty or, in other words, a lower risk of failure is feasible, a management towards a high stress tolerance (high resilience) remains necessary.

One important way to tackle uncertainty and complexity in freshwater resource management is adaptive management. Adaptive management is an integrated, multidisciplinary approach for confronting uncertainty in natural resources issues. It is “adaptive“ because it acknowledges that managed resources such as freshwater will always change as a result of human intervention, that surprises are inevitable, and that new uncertainties will emerge. Adaptive management acknowledges that policies must be continually modified and flexible for adaptation to these changes.

Session 2:

Climate change impacts on water quality – nutrients, organic content, toxic compounds, ecological status and biodiversity

Status and requirements for climate change research in European regional seas

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Within the last two decades, recurrent scientific evidence indicates that environmental changes are occurring at all scales with profound impacts on European seas and coasts. The major observed and projected changes related to marine environments include the increase of water temperature, the sea level rise, reduction of Arctic and Baltic sea ice, changes in salinity distribution in N. Atlantic and the European Sub-arctic and Arctic regions altering water exchange between those basins, marine acidification, and increased frequency of extreme events like heat waves, rainstorms, and coastal surges. Temperature increase has enabled northward migration of some warm water species while making it indispensable to some cold water species. Combined with timing shifts of biological key processes like hatching, reproduction, foraging, and formation of resting stages, changes in species composition may cause mismatch in prey-predator relationships and will endanger the marine food-web structure.

Upon a request from the European Water Directors, with support from the DG Environment, the Institute for Environment and Sustainability (JRC-IES) organized a European Expert Workshop (April 26-28th, 2006) with the goal to review climate change issues in relation to the European marine environment, to identify gaps in our current scientific and technical knowledge, and to investigate the implications for European Policies to focus on adaptation and mitigation strategies to marine climate change. The Workshop was structured into four sessions: Systematic Observations and Networks, Modelling and Data Synthesis, Ecosystem Impacts and Coastal Responses, and Mitigation and Policy adaptation Strategies.

A report of the workshop is now under preparation. Following a brief description of most marked indications of climate change in the European seas and coasts, the Report addresses some elements and recommendations that would contribute to a better understanding of the present and future status of our Seas. Some attention is given to management measures that have been established or considered in response to environmental changes, looking at different sectors, as well as through the development and implementation of European policies. The following measures were highlighted at the Workshop that would be required in order to increase the knowledge base and reduce the uncertainty of projections:

1. Establishment of long-term surveillance monitoring schemes with appropriate funding mechanism to ensure continuity of the measurements over long periods.
2. Establishment of operational monitoring of the water exchange between the N. Atlantic and European Sub-arctic and Arctic marine areas.

3. Technology development (e.g. autonomous platforms, gliders, near-surface and profiling floats) to second expensive and, thus, occasional oceanographic cruise campaigns
4. Wider use of Earth Observation Satellite data to reduce uncertainties in essential climate variables.
5. Wider use of geo-spatial technologies to monitor changes in coastal morphology.
6. Enhancement of Regional Climate Models and coupling them with 3-D regional hydrodynamic and biogeochemical models.
7. Further investigation of carbon sinks and sources in shelf and coastal seas and their feedback on climate.
8. Further investigations of the combined effect of elevated temperature and reduced pH on marine food webs.

The use of Emission Reduction Plan and EU compliance to Kyoto Protocol remains extremely important to mitigate climate change impacts on the marine environment.

A new technology - deliberate underground or marine storage of anthropogenic CO_2 in geological structures like the North Sea gas fields has several pros and contras. Despite the technical feasibility and high potential, the capturing and undersea storage of liquid CO_2 requires the application of the precautionary principle and a further environmental safety evaluation. The technology is still in the testing phase as the reactions of surrounding medium to changes in acidity as well as the effects of elevated concentrations of CO_2 (in the case of potential leakage) on terrestrial and marine ecosystems are largely unknown.

Session 2:

Climate change impacts on water quality – nutrients, organic content, toxic compounds, ecological status and biodiversity

Impacts of climate change on cycling, accumulation and feedbacks of chemicals in aquatic ecosystems

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Introduction

Many organic chemicals, such those considered as Persistent Organic Pollutants, have potential for persistence, bioaccumulation and long-range transport in the environment. These chemicals, once released in the environment are subject to two types of processes; namely, partitioning between different environmental phases (sediments, air, biota, soils, water….) and spatial transport and phase advection due to processes such as atmospheric deposition, bioaccumulation, currents, settling of particles in the water column and degradation. Temperature does exert directly a influence on partition, so that higher temperatures will induce higher concentrations of organic chemicals in water and air and lower in sediments and soils, respectively. These and other influences of temperature changes on POP cycling can be modeled with moderate confidence. Nevertheless, the major challenge when trying to assess the impact of climate change on pollutant cycling and feedbacks comes from the current understanding of non-partition processes and how they respond to perturbations. In particular, processes related to the hydrological cycle, to the trophic structure of the foodweb, etc. In addition, uncertainty is also due to potential future scenarios of precipitation patterns, snow and permafrost melting as well as on prediction of ecosystem trophic structure. Much research is needed to better estimate the interactions and feedbacks between chemicals, climate and ecocystem functioning. However, as has been noted elsewhere, perturbation on the hydrological and carbon cycles can lead to important modifications on POP sinks and to higher concentrations in some environmental compartments (Macdonald et al. 2003).

Impact of climate change on cycling of POPs

The atmosphere does play a key role redistributing POPs to pristine environments. Figure 1 shows annually-average atmospheric deposition for the European Seas for a representative PCB (following Jurado et al. 2005). The two more important processes are wet deposition and diffusive exchange. These two processes are highly dependent on the precipitation regime and the biological pump (Dachs et al. 2002, Jurado et al. 2004), and therefore, any perturbation on these processes will lead to changes in POP loading to European seas, both in quantity and spatial distribution. There are many examples of processes that can lead to changes in POP cycling and induce an increase of exposure in pristine remote ecosystems. Furthermore, soils are the main reservoir of POPs and the increase of temperature in some European regions by just few degrees can remobilize important historical burdens of POPs that otherwise would be kept immobilized /buried. Climate change, with its changes in temperature and precipitations, water use, etc, will also affect the accumulation of POPs in aquatic ecosystems. A recent study has shown by simulating POP cycling in high altitude lakes that accumulation of highly hydrophobic POPs in these lakes will decrease (Meijer et al. 2006), indicating also a higher potential of POPs for long range transport and thus impacting pristine areas such as the Arctic, etc. Briefly, the change in ecosystem functioning will induce changes in POP cycling that can induce important remobilization of historical pollutants and affect substantially as well the fate of new and emerging pollutants to ecosystems.

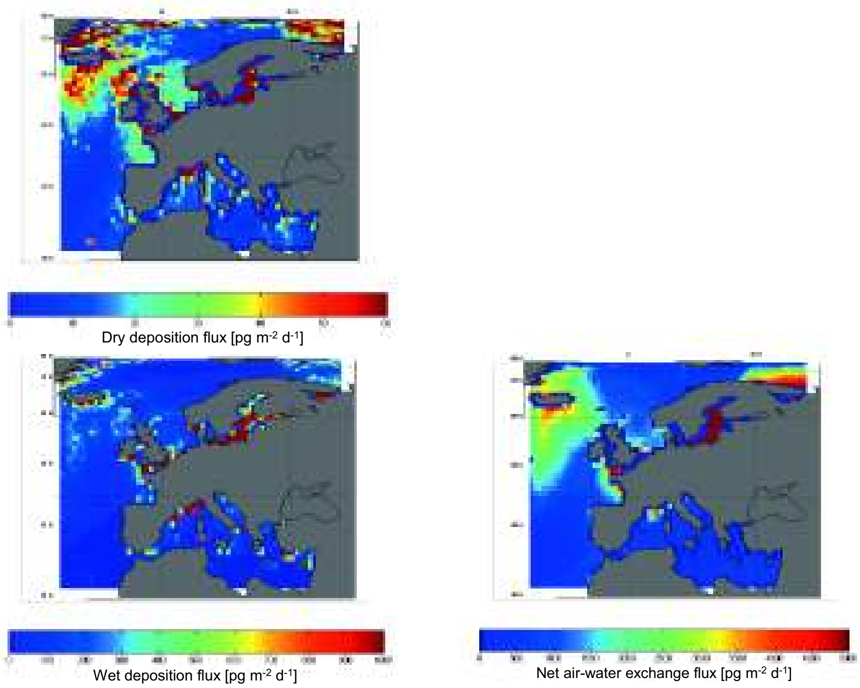

Figure 1: Atmospheric deposition of PCB 153 to the European Seas.

Impact of climate change on chemical related risks

Even though high uncertainties are present in our understanding of how these changes in cycling and exposure routes, still it is possible to draw some trends for the increase of risk associated to POP higher mobility. In fact, it is accepted that the induced changes in regional and global distribution of POPs will change the exposure of biota to these chemicals, increasing the risk for some species (Macdonald et al. 2005). Furthermore, changes in food webs due to invading species and/or climate changes can induce dramatic changes in pollutant transfer routes and thus provoke important changes in bioaccumulation potential, which is the result of a complex coupling of biological and physical processes. Changes in environmental concentrations of POPs are expected to be faster in the atmospheric phases, and thus what is needed is a complete understanding of how water and biota will respond to changing environmental concentrations and status. Furthermore, in a global change scenario in which extreme events may be more common, high amounts of POPs can be reintroduced in the environment and these pulses can have regional impact. Many POPs are immunotoxic chemicals and their effects can be linked to changes in species migratory behavior and trophic status. For example, Heide-Jorgensen et al. (1992) suggested that harp seals having migrated from the Barents Sea to northern Europe waters and lacking prior exposure to PCBs could have provided the foundation for an epidemic. Ross et al. (2002) have reported cases where the exposure to POPs have facilitated the spreading of disease in natural communities under a anthropogenic perturbed scenario.

Even though the field of study of the feedbacks between climate change, POP cycling and ecosystem status is in its infancy, the current knowledge suffices to state that feedbacks between climate change and POPs occur and are significant. Further research is needed to better understand these processes and identify areas were political actions are needed.

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Session 2:

Climate change impacts on water quality – nutrients, organic content, toxic compounds, ecological status and biodiversity

Climate change impacts on aquatic ecosystems: critical thresholds for water policies

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Responses of ecosystems, particularly aquatic ones, to external forcing typically involve non-linear responses, with sudden, step change occurring once particular levels of the pressures are exceeded. These threshold responses are prevalent in aquatic ecosystems and frequently involve a regime shift or dramatic reorganisation of the system where the system is qualitatively changed with the emergence of different control processes and buffers to those operating before the threshold was exceeded. These thresholds are difficult to revert as systems experiencing threshold responses are also likely to exhibit histeresys in their responses, where the pressures operating on the system must be reduced far below the threshold level if the system is to return to the original state. Often, however, the system fails to return to the original status and the thresholds represent, therefore, points of no return beyond which operational irreversible shifts in the ecosystems occur.

Whereas research on thresholds have focus on point-source disturbances, such as eutrophication and pollutant inputs, climate change may also induce threshold-like responses in aquatic ecosystems. These are, however, poorly studied or remain entirely ignored both in scientific research and policy formulation.

In this presentation I will review potential threshold responses of European aquatic ecosystems, both freshwater and marine, to climatic change. Threshold responses discussed shall include: (1) thresholds for aquatic hypoxia related to increased water temperature; (2) thresholds for the proliferation of invasive and noxiuous species related to increased water temperature; (3) thresholds for ecosystem integrity associated to climatic changes in rainfall and evaporation, among others. I shall also discuss the potential synergies between direct anthropogenic pressures and the more diffuse pressures resulting from climate change and how they may impact on the status of aquatic ecosystems.

These climatic-driven threshold responses have direct consequences for water policies, affecting, for instance, the capacity to revert deteriorated water bodies to good condition. Indeed, many drivers of the background conditions of aquatic ecosystems, such as CO_2 concentrations, water temperature and metabolic rates, and hydrological budgets are changing as part of global climate change. The static approach that has prevailed in the definition of water policies so far must be replaced by a new generation of policies based on the concept of shifting baselines, where targets and actions are designed that consider the

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broad, global changes in key components of the functioning of the biosphere. Failing to provide both the knowledge base and the associated policies addressing these shifting baselines in an adaptive manner may lead to failure to reach policy targets aiming at sustainable development and the consequent frustration of the European society.

Session 2:

Climate change impacts on water quality – nutrients, organic content, toxic compounds, ecological status and biodiversity

Climate change and projection on water quality changes in Europe Aquatic ecosystem responses to climate change: past, present and future

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1. Introduction

Although GCMs vary in their projection of future climate change all are in agreement that significant warming will occur within this century, principally as a result of a continued rise in the concentration of greenhouse gases.

Exploring implications of future warming for European aquatic ecosystems will need (i) robust projections of future climate change at a spatial scale appropriate for ecosystem assessment; (ii) realistic scenarios for future changes in land-use and pollution across Europe; (iii) a process-based understanding of how climate change will affect the structure and function of aquatic ecosystems both directly (as a result of changes in climate variables) and indirectly, through interaction with other stressors; and (iv) the development and re-evaluation of policies, protocols and directives needed to sustainably manage aquatic ecosystems in the face of significant climate change.

Assessing the likely impact of future climate change needs a range of different approaches used in combination, including (i) statistical and process-based modelling; (ii) analysis of long-term observational physical, chemical and biological data-sets; (iii) palaeolimnological reconstructions to extend time-series and explore processes over longer time-scales; (iv) the use of space-time substitution on the assumption that future climate analogues can be found in space (altitude, latitude); and (iv) conducting experiments in laboratories or in the field under controlled climate conditions.

2. Direct impacts of climate change on aquatic ecosystems

Projected changes in climate will have far-reaching impacts on the physical, chemical and biological characteristics of many if not all European freshwater ecosystems. There is clear evidence already for increasing stream and lake surface water temperatures, especially in the Alps, hypolimnetic warming in large lakes, decreasing ice-cover in northern and high altitude lakes, decreasing stream flow and lake level in southern regions, changes in conductivity, alkalinity and nutrient loading in mountain lakes, changes in seasonality of phytoplankton, especially earlier spring blooms, alterations to aquatic invertebrate life-cycles, changes in the geographical range of taxa, an extension to growing seasons and increases in lake productivity.

3. Interaction between climate change and other stressors

Indirect impacts of climate change through interactions with other stressors on ecosystems may be equally as important as direct impacts, but more difficult to predict and model.

Climate-hydromorphology interactions. One of the key concerns for streams and rivers systems is how future changes in hydrology and land–use change as a result of climate change will influence stream and river discharge and channel morphology that in turn control riparian and channel habitat structure and species diversity. Understanding these relationships will be essential if current and proposed schemes for the re-naturalisation of river channels are to be sustainably designed.

Climate-eutrophication interactions. Whilst there have been major successes in Europe in reducing problems at many sites eutrophication still remains Europe's most serious problem for freshwaters, especially for shallow lakes and sites where diffuse pollution sources dominate nutrient loading. In almost all situations climate change will make eutrophication a more difficult problem to control. Growing seasons will lengthen, algal biomass will be encouraged by warm, sunny weather, hypolimnetic oxygen conditions may deteriorate, and cyanobacterial blooms may become more extensive and possibly more toxic. For shallow lakes these problems may be exacerbated by food chain effects, especially by a shift to more intense fish predation and reduced zooplankton populations in a warmer climate.

Climate-acidification interactions Following more than two decades of decreases in sulphur dioxide emission, surface waters across upland Europe are beginning to recover from the effects of acidification. However a full recovery will take many decades, and the time-scale and speed of recovery may be influenced by climate change. In some cases the influence may be positive, where warming promotes alkalinity generation and reduces the intensity of spring snow-melt episodes. In other cases the effect may be negative where increased storminess, especially in maritime regions, increases the severity of high discharge events in streams and where increased winter precipitation and surface flows lead to an increase in the dilution of base cations.

Climate and toxic substance interactions Although many of the most toxic substances introduced into the environment by human activity have been banned or restricted in use, many persist, especially in soils and sediments, and either remain in contact with food chains or can be re-mobilised and taken up by aquatic biota. The high levels of metals (e.g Hg, Pb) and persistent organic pollutants (PCBs, DDE) in the tissue of freshwater fish in arctic and alpine lakes attest to the mobility and transport of these substances in the atmosphere and their concentration in cold regions. For aquatic systems with long food chains biomagnification can elevate concentrations in fish to lethal levels for human consumption. The major concern with respect to climate change is the extent to which toxic substances will be remobilised and cause additional contamination and biological uptake in arctic and alpine freshwater systems as water temperatures rise, and whether storm events and flooding might increase soil and sediment erosion and lead to the re-mobilisation of metals and persistent organic compounds. In the case of Hg, changing hydrology in Boreal forest soils may lead to the enhanced production of MeHg.

4. Implications for policy and management

The impact of climate change is likely to be so far reaching that all national and EU policies related to environmental protection will probably need thorough re-evaluation. For freshwater ecosystems there are potentially major implications for the Habitats Directive, the Urban Wastewaters Directive and the Water Framework Directive. Polices relating to biodiversity and conservation will need to make allowance for geographical shifts in the range of species, and for changes in the nature of aquatic habitats both chemically and morphologically. This might include the need for EU countries to work more closely together by assigning conservation value at the continental rather than national scale, integrating activities to provide migration corridors, improving habitat connectivity and being alert to the impacts of climate change on the potentially disruptive effect of invasive alien taxa and pathogens.

For the WFD and other policies associated with environmental restoration, climate change has serious implications. In particular (i) the reference state, although valuable as a concept, may be unstable for many freshwater systems over the longer term as reference sites themselves are subject to change; and (ii) restoration targets for disturbed systems may not simply be achieved by removing stresses, as how those stresses interact or might interact with climate change in future will determine the directions in which ecosystems trend.

5. Future needs

To understand better how future climate change will affect freshwater ecosystems it will be necessary to:

- Continue to generate high resolution climate models that project probable future climate change at the regional scale
- Generate realistic scenarios for future changes in pollution and land-use that are influenced by climate change
- Continue to perform critical experiments that explore the impacts of climate change on aquatic ecosystems
- Continue to develop system specific models to simulate probable hydrochemical and ecological responses to climate change
- Continue to develop coupled models that are able to simulate catchment scale responses to climate change
- Continue to invest in high quality monitoring programmes to provide early warning of future changes and to provide long-term data-sets for model calibration and verification
- Establish an array of appropriate chemical and biological indicators for detecting climate change effects
- Continue to promote integration amongst the otherwise fragmented freshwater science community in Europe
- Invest in central databases for hydrological, hydrochemical and hydrobiological data to enable model development and upscaling to the regional and continental levels
- Improve the interaction between water managers and freshwater scientists to enable intelligent data analysis and decision making in restoring ecosystem quality.

SESSION III

ECONOMIC AND SOCIAL IMPLICATIONS ASSOCIATED WITH CHANGES IN THE WATER CYCLE AND RESOURCES INDUCED BY CLIMATE CHANGE

Session 3:

Economic and social implications associated with changes in the water cycle and resources induced by climate change

Summary and main highlights:

Climate change induces alterations in the spatial and temporal distribution of water, as well as in its quality. These changes affect the occurrence of natural disasters and have an impact on several socio-economic sectors, such as agriculture, energy production, land use and human health. Due to the diversity across Europe in water uses and pressures, the impacts are regionally different and can be either positive or negative, depending on the sector. For example, climate-related increases in crop yields are expected in Northern Europe, while Southern Europe is likely to see lower crop yields. Regionally different impacts may produce competition in land use (crops that will become more, or less, suitable in some regions), or energy sources (wind or hydropower energy sources may become more, or less, profitable in particular regions). Adaptation is needed on a regional and local scale to anticipate the projected changes.

However, in most socio-economic sectors, current knowledge and data are insufficient to reliably quantify the expected changes and to assess the effectiveness of adaptation strategies. There is a need for:

- better understanding and quantification of the physical and ecological impacts of climate change through improved (geophysical and ecological) modelling and collection and analysis of field data,
- better understanding and quantification of economic and social impacts of climate change in the different socio-economic sectors (through integration of geo- and biophysical models with socio-economic models),
- better understanding and quantification of uncertainty throughout the chain of "emissions → climate → physical/ecological impact → socio-economic impact", for example through the use of multi-model ensemble approaches that probe the respective uncertainty spaces,
- better understanding and quantification of costs and benefits of adaptation strategies in view of an uncertain future,
- better understanding and quantification of vulnerability and adaptive capacity of receptors to change,
- coherent and consistent potential changes in land use, water cycle, climate and socio-economic systems, including feedbacks and interactions.

Even though the projected impacts are highly uncertain, possible effects of climate change should be considered in the relevant policies for the different sectors, as is partially the case in the proposed directive on floods. However, in the latter, projected changes in climate should not only be considered in the preliminary risk assessment, but also in the flood risk maps and management plans. Other examples of where climate change considerations should be incorporated are the Common Agricultural Policy, Water Framework Directive, Habitat Directive and Soil Strategy. Appropriate taxing and pricing of emission-free energy sources can make them more competitive and mitigate future climate changes.

Policy-makers should strike a balance between the costs of adaptation measures as incurred today and their potential benefits for the future, including environmental benefits. Decisions should be based on the precautionary principle, as it provides policy-makers with the possibility of installing measures even where there is still uncertainty about a problem. Climate change policy requires integration across scientific disciplines, policy areas, socio-economic sectors and stakeholder groups to develop sustainable adaptation strategies.

Session 3:

Economic and social implications associated with changes in the water cycle and resources induced by climate change

Impacts of climate change in Europe: The PESETA project

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Objectives and scope of the PESETA project

The objective of the PESETA project (Projection of Economic impacts of climate change in Sectors of the European Union based on boTtom-up Analysis) is to make an assessment of the monetary estimates of impacts of climate change in Europe (including EU25 and Rumania, Bulgaria and Turkey) in the 2011-2040 and 2071-2100 time horizon, based on bottom-up physical assessments. The project largely benefits from DG Research projects that have developed impact-modelling capabilities (e.g. the DIVA model) and high-resolution climate scenarios for Europe (the PRUDENCE project). PESETA is designed to be of policy relevance for DG Environment.

The PESETA project focuses on the following sectoral impacts: Coastal systems, Energy demand, Human health, Agriculture, Tourism, and Floods. Each of these sectoral categories comprehends a sectoral study in the corresponding field carried out by the partners of the project, considering cross-sectoral issues.

The socioeconomic and climate scenarios

A key issue in the PESETA project is the use of the same set of socioeconomic and climatic scenarios in all the six sectoral studies. JRC/IPTS (the coordinator of the project), the partners in charge of the sectoral studies and the multidisciplinary PESETA Advisory Board agreed on using the following scenarios for the two time windows of the project:

- for the 2011-2040 time span: the A2 socioeconomic SRES scenario with the RCA3 model and ECHAM4 boundary conditions; this database comes from the Rossby Centre, which has kindly provided the required 50-km resolution data from its transient climate scenario.
- for the 2071-2100 time horizon: the A2 and B2 socioeconomic SRES scenarios for two regional climate models (HIRHAM, RCAO) and two global circulation models (ECHAM and HadAM3H) models. All this climate data come from the PRUDENCE project.

Methodological approach

The project is characterized by a quantitative or model-based assessment of impacts of climate change where the general approach for estimating monetized impacts starts from detailed studies on physical impacts. The purpose is not to give single values of damage or impact of climate change, but to explain the plausible ranges of impact of climate change. Once the physical impact results are obtained, benchmark values in terms of euros per unit of physical impacts are used to convert these into monetary estimates. Various adaptation schemes will be considered, including the non-adaptation and private adaptation cases.

In general, there are two methodological approaches in the sectoral studies:

- Process modelling in the sectors Agriculture, Coasts, and Floods. The impacts in those sectors are assessed through detailed modelling systems: the LISFLOOD model for Floods, the DIVA model for Coasts, and the DSSAT model for Agriculture. In the three sectors, the models are ready-to-use.
- Exposure-response functions. The other three sectors follow a more simplified framework in which the direct relationships between climate variables and impacts are considered. For the case of Human health, the exposure-response functions are based on the related literature. For Energy and Tourism they come from statistical and econometric analysis. In these two sectors there is a significant work to be done both concerning data gathering and statistical analysis.

Some issues on the economic assessment in PESETA

The presentation focused in a second part in some key issues related to the economic assessment in the PESETA project. The monetary valuation of the physical impacts of climate change is a potentially controversial issue in any impact assessment study. There are several methods that can be used to estimate the effects of the climate impacts on the economic system, such as partial and general equilibrium models. In the PESETA project, the Agriculture, Coasts and Energy sectoral studies will use computable general equilibrium models. Some studies take valuation estimates from the literature, the so-called benefit transfer approach, a method followed by the Health sector study.

Once the monetary effects are computed, they must be aggregated across regions/countries and time. The choice of the spatial and time weights is always subject to value judgements, which partly explains the noted controversy. One way to address the noted difficulties is to make sensitivity analyses to the key assumptions used in the various sectoral assessments of the PESETA project.

Preliminary results

The project is running in 2006 and is to be finished by the beginning of 2007. There are preliminary results for the fluvial floods sectoral study (Feyen et al., 2006).

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Session 3:

Economic and social implications associated with changes in the water cycle and resources induced by climate change

Water resources and climate change: Impacts on agriculture in Europe

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Introduction

The hydrological features in Europe are very diverse, and there is also a large diversity in water uses, pressures and management approaches. About 30% of abstracted fresh water in Europe is used for agricultural purposes, primarily irrigation (Flörke and Alcamo, 2005). Although the quality of river water is improving in most European countries (Nixon et al., 2003), the impact of agriculture on Europe's water resources needs to be reduced if "good ecological" status of surface and ground water is to be achieved as required by the EU Water Framework Directive. There are many pressures on water quality and availability including those arising from agriculture, industry, urban areas, households and tourism (Lallana et al., 2001). Recent floods and droughts have put additional stresses on water supplies and infrastructure (Estrela et al., 2001).

Climate change is expected to affect agriculture very differently in different parts of the world (Parry et al., 2004). The resulting effects depend on current climatic and soil conditions, the direction of change and the availability of resources and infrastructure to cope with change. There is a large variation across the European continent in climatic conditions, soils, land use, infrastructure, political and economic conditions (Bouma et al., 1998). These differences are expected also to greatly influence the responsiveness to climatic change (Olesen and Bindi, 2002). Intensive farming systems in Western Europe generally have a low sensitivity to climate change (Chloupek et al., 2004). On the other hand some of the low input farming systems currently located in marginal areas may be most severely affected by climate change (Reilly and Schimmelpfennig, 1999).

Climate change impacts

Climate-related increases in crop yields are only expected in Northern Europe, while the largest reductions are expected around the Mediterranean and in the Southwest Balkans and in the South of European Russia (Olesen and Bindi, 2002; Maracchi et al., 2005; Alcamo et al., 2006). In Southern Europe, particularly large decreases in yield are expected for spring-sown crops (e.g. maize, sunflower and soybeans) (Audsley et al., 2006). Whilst, on autumn-sown crops (e.g. winter and spring wheat) the impact is more geographically variable, yield is expected to strongly decrease in the most Southern areas and increase in the northern or cooler areas (e.g. northern parts of Portugal and Spain) (Olesen et al., 2006).

Some crops that currently grow mostly in Southern Europe (e.g. maize, sunflower and soybeans) will become more suitable further north or in higher altitude areas in the south

(Audsley et al., 2006). The projections for a range of SRES scenarios show a 30 to 50% increase in suitable area for grain maize production in Europe by the end of the 21st century, including Ireland, Scotland, Southern Sweden and Finland (Hildén and Lehtonen, 2005; Olesen et al., 2006). Moreover, by 2050 energy crops show a northward expansion in potential cropping area, but a reduction in suitability in Southern Europe (Schröter et al., 2005).

Climatic variability and extremes

Recent results indicate that variability in temperature and rainfall may increase considerably over large parts of central Europe (Christensen and Christensen, 2002; Schär et al., 2004). Indeed heat waves and droughts similar to the 2003 situation may become the norm in central and southern Europe by the end of the 21st century (Beniston and Diaz, 2004). This heat wave led to substantial reductions in primary productivity of terrestrial ecosystems and large and widespread reductions in farm income (Olesen and Bindi, 2004; Ciais et al., 2005).

Regional climate models have shown that global warming may be linked with a shift towards heavier intensive summertime precipitation over large parts of Europe (Christensen and Christensen, 2002). The precipitation events over central Europe may therefore occur more frequently in the future (Pal et al., 2004). The severity of the floods was probably enhanced by human management of the river systems and by the agricultural land use in the river basins.

Water requirements

Agricultural water use will be impacted not only by changes in timing and amount of rainfall, but also be the increased evapotranspiration under warmer and drier summer conditions. Changes in the water cycle are likely to increase the risk of floods and droughts. Projections indicate that the risk of floods increases in almost all of Europe, while the risk of drought increases mainly in Mediterranean and Eastern Europe (Lehner et al., 2005).

The river basin area affected by severe water stress increases under some scenarios due to both climate change and increasing water withdrawals and will lead to increasing competition for available water resources (Alcamo et al., 2003; Schröter et al., 2005). The regions most prone to an increase in water stress are the Mediterranean (Portugal, Spain) and some parts of Central and Eastern Europe, where the highest increase in irrigation water demand is projected (Döll, 2002). Irrigation requirements are likely to become substantial in countries where it now hardly exists (Holden et al., 2003). The irrigation demands will also be influenced by changes in the amount and distribution of agricultural land as affected in the future by the EU Common Agricultural Policy (CAP). Irrigation requirements will be strongly influenced by effects of climate changes on the timing of the growing season for specific crops, e.g. maize, which in some cases may maintain irrigation requirements at current levels (Minguez et al., 2006).

Nutrient losses and soil quality

Environmental impacts of agriculture under a changing climate are becoming more and more important. In particular, the role of nitrate leaching on the quality of acquifers, rivers and estuaries is globally recognized (Galloway, 2004). Projections made at European level for winter wheat showed for the 2071-2100 time-slice large spatial variations in changes in N-leaching, depending on both soil and climatic conditions (Olesen et al., 2006).

The climate change scenarios could also lead to increases in greenhouse gas emissions from agriculture. Increasing temperatures will speed decomposition where soil moisture allows, so direct climate impacts on cropland and grassland soils will tend to decrease SOC stocks for Europe as a whole (Smith at al., 2005). This effect is greatly reduced by increasing C inputs to the soil because of enhanced NPP, resulting from a combination of climate change and increased atmospheric CO2 concentration. However, decomposition becomes faster in regions, where temperature increases greatly and soil moisture remains high enough to allow decomposition (e.g. North and East Europe), but does not become faster where the soil becomes too dry, despite higher temperatures (Southern France, Spain, and Italy) (Smith et al., 2005).

Adaptation in agriculture

Long-term adaptations include major structural changes to overcome adversity caused by climate change. This involves changes in land allocation and farming systems, breeding of crop varieties, new land management techniques, etc. This involves changes of land use that result from the farmer's response to the differential response of crops to climate change. The changes in land allocation may also be used to stabilise production (reducing yield variability) and for conservation of soil moisture. Other examples of long-term adaptations include breeding of crop varieties, new land management techniques to conserve water or increase irrigation use efficiencies, and more drastic changes in farming systems (including land abandonment).

Recent studies at European level have demonstrated the need to include changes in climate and non-climate factors (technological, socio-economic, etc.) for assessing the changes in crop yield and suitability (Schröter et al., 2005). A different allocation of European agricultural land use represents one of the major long-term adaptation strategies available. Rounsevell et al. (2005) estimate a decline of up to 50% in cropland and grassland areas under some of the IPCC SRES scenarios.

It is indisputable that the reform of European Union agricultural policies will be an important vehicle for encouraging European agriculture to adapt to climate change (Olesen and Bindi, 2002). However, policies for managing European water resources under a changed climate may have equally high impacts on agriculture.

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Session 3:

Economic and social implications associated with changes in the water cycle and resources induced by climate change

Long-term planning of flood risk management

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1. The concept of flood risk management in the long term

Flood risk in general can be understood as the probability of negative consequences due to flooding. It occurs in a complex cascade of natural and societal processes leading from the triggering hydrometeorological hazards to the social, economic and ecological impacts depending on the flood vulnerability. This cascade may be described by the source-pathway-receptor-consequence-model or more sophisticated by flood risk systems of a river catchment or a hydraulically connected coastal cell.

Flood risk management is dealing with the governance of such systems. It covers a 'holistic and continuous societal analysis, assessment and reduction of flood risk'. Hereby, 'holistic' refers to whole flood risk system and 'continuous' expresses the need for its ongoing monitoring and steering by the society. Representatives from responsible institutions are the predominant managers. These actors decide on the tolerability of risks and than design and implement physical measures and policy instruments for risk reduction. Decision-making and development follow a process pattern and consider external demands of the society and behave in line with individual context conditions.

In contrast to the short-term management of running flood events, long-term planning focuses on the formulation, implementation and controlling of strategies for future flood events. It is dedicated to concrete actions in the medium term (up to 10-20 years) or more explorative for an explicit long term (up to 50-100 years). In the medium term, the predominant interest is to decide on measures and instruments to reach defined goals. The long time horizon additionally has to take into account that some factors of flood risk systems are a subject to a significant dynamic through external and internal drivers. For instance, flood hazards are sensitive to climate change; the flood vulnerability evolves according to land-use change. Therefore, planning needs to explore the system's dynamic with its impacts on future risks and to reflect the suitability of alternative strategies under the condition of an uncertain future. Hereby, the predictability of the future is restricted which also causes certain requirements for the management process itself.

2. Requirements due to climate change and other dynamic factors

Recent climate change projections indicate a tendency of more frequent and intensive flood events. Results differ depending on the regional conditions, which for example may lead to an increase or decrease of the superposition of heavily rainfall with snowmelt. They also vary with respect to the downscaling method and the combination of climatic and hydrological models applied. Especially the coarser temporal and spatial resolution of climatic models in comparison to hydrological models currently still limits detailed simulations. Furthermore, time-series of measurements of rainfall and runoff are relatively short which constrains a statistical assessment of future events in the context of historical events. And last but not least, the underlying assumptions of the formulation of climate scenarios are unavoidable manifold. Accordingly, uncertainties referring to the impacts of the running climate change on flood hazards remain rather high.

Especially the alteration of flood frequencies and intensities could lead to a number of changes in flood risk systems. They may require a rework of the hydrological, statistical and hydraulic baselines for the determination of flood hazards and design levels. If water levels increase, enhanced efforts to maintain the current design standards of flood prevention would be needed. For example, this could lead to an enlargement of active floodplains, the re-design of reservoirs and flood polders, heightening and strengthening of flood defence structures etc. Moreover, secondary effects could be expected like changing benefit-cost-ratios for measures and instruments of risk reduction for both resistance and resilience strategies.

As flood risks occur only due to the flood vulnerability of the society, developments of societal factors of flood risk systems are an important issue of long-term projections in addition to climate change. Land use as one major factor of vulnerability – beside its effects on runoff and hydraulic performance of flood plains – is determined by a significant dynamic in the medium and long term with drivers like demography, economic development and others. As investigations show from the Rhine River valley, a doubling of vulnerability in 20-30 years is a realistic assumption. This stresses the meaning of the dynamic of the societal processes as one aspect of the exploration of possible futures. Accordingly, it is another source of uncertainties.

What do the natural and societal dynamic and inherent uncertainties of future developments of flood risk systems mean for long-term flood risk management? Firstly, a strategic planning approach should be applied exploring and reflection alternative future projections. Secondly, measures and instruments decided on should follow precautionary principles (e.g. ‘no regret’) and ensure sufficient flexibility and robustness under the given uncertainties. Thirdly, management should be based on learning on effects of previous decisions and the recent system developments as well as on consistent behaviour of decision makers and emergent decision-making pattern.

3. State of the Art on European and National Level

Flood research up to now predominantly is focussing on hazard determination and flood forecasting. Vulnerability analyses are gradually evolving with an emphasis of asset calculations. Investigations on a comprehensive long-term flood risk management are still in an initial phase. One important study is Foresight Future Flooding in United Kingdom. It focuses on a wide spectrum of factors relevant for flood risks using a 10 km grid resolution on the national level and a time horizon till the end of the 21st century. The drivers taken into account range from downscaled IPCC scenarios to socio-economic developments like demography and GDP. The study concluded with an impact assessment of alternative futures which show a tremendous increase of risks due to flooding within this century.

Currently, the 6th Framework Programme Integrated Project FLOODsite in one task is developing and testing a methodology to combine climate change and other relevant societal trends with strategic alternatives of risk reduction measures and instruments to explore alternative futures on the catchment and estuarine level, respectively. Moreover, coupled models and criteria will be provided for a multi-criteria impact assessment of such futures. As result, the effectiveness, sustainability, flexibility, robustness etc. of risk reduction measures and instruments under different climate and societal change projections will be available. The FLOODsite methodology will be well documented to allow a general applicability.

In close collaboration, the VERIS-Elbe research project under the German RIMAX-Programme is dealing with a further detailing of fluvial flood risk systems and a methodology for a highly resolved simulation of the dynamic of flood risks. It covers the issue of the spatial scale of large river catchments based on the example of the Elbe River and the temporal scale developing new extreme value statistics. Hereby, cooperation with the Elbe study of DG Joint Research Centre has been established. Beside the simulation of the flood risk system, VERIS-Elbe covers also investigations on spatial planning instruments for the long term.

Studies on an integrated and strategic long-term planning in flood risk management are rare till now. Under the first call of ERA-NET CRUE an upcoming project will deal with risk perception of decision makers and decision strategies on physical measures and policy instruments. As investigations on river basin management let assume, the meaning of the institutional context of relevant actors as well as the management process itself may not be underestimated in terms of the societal ability to adapt to climate and societal change.

Against this background, the following research demands can be concluded. Methodologies on integrated and regionalised projections of future flood risk systems should be improved considering all significant drivers and probable options of combined resistance and resilience strategies. Analyses of such futures moreover need the further development of coupled interdisciplinary simulation models with a specification of their uncertainties. Currently, model uncertainties seem partly to be higher than impacts of climate change. Improvements should regard to the interfaces between climatic downscaling and hydrological models as well as between hydrodynamic models and methods for vulnerability analyses. For the latter, a better resolution is evident to more validly determine climate change impacts and to calculate risks in comparison to benefits of using flood-prone areas. In terms of policy instruments and the management processes, an enhancement of current social and planning science knowledge is needed. Real-world planning seems to be crucial for the improvement of the effectiveness of risk reduction efforts for European citizens. Climate and societal dynamics especially require the treatment of different time horizons with different levels of accuracy and instruments which for instance should reflect experiences from strategy research.

4. Reflection of current European Water Policy

The proposal of a Directive on the Assessment and Management of Floods already contains the demand to consider future flood risks as part of the preliminary flood risk assessment (Chap. II). This seems to be an important step towards the generation of knowledge on the impact of climate change on flood risks in European Member States. To strengthen the treatment of the dynamic of flood risk systems, it would be valuable to specify how future flood risks should be proactively reflected in risk maps (Chap. III) and in the flood risk management plans (Chapt. IV). Especially, the display of remaining risks in both maps and plans could provide information on inherent uncertainties due to climate and societal change. Further on, adaptive management strategies for flood risks need to be developed and tested.

The proposed coordination with the Water Framework Directive (WFD) allows an identification of increasing conflicts between water quality and flood risk issues due to climate change. Therefore, the WFD needs to be enhanced with respect to climate change.

Moreover, river basin and flood risk management should be compiled as two separate but well integrated items in a comprehensive plan.

Measures and instruments for flood risk reduction funded via the Cohesion Policy and Common Agricultural Policy/Rural Development should be bound on the elaboration and treatment of integrated scenarios on alternative futures (30-100 years) on the regional and local level. Priorities for policy on research to improve the scientific capacity of adaptation particularly in the 7th Framework programme are already mentioned above. In general, climate change policy requires a cross-sectoral collaboration of various policy areas where water management and spatial planning are supposed to have the major responsibility for integration and the development of adaptive and sustainable strategies.

Session 3:

Economic and social implications associated with changes in the water cycle and resources induced by climate change

Land use and climate change

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Background

The Land Use Sector is thought to be both a culprit and a potential victim of climate change. It is a culprit because expansion of global cropland, pasture and built-up area contributed to a release of carbon in the range of 230 to 258 GtC over the period from 1700 to 2000 AD. About 57 % of this release are caused by the expansion of pasture. In the EU agriculture is the third largest sector of greenhouse gas emissions, accounting for 9 % of EU-25 emissions and 10 % of EU-15 greenhouse gas emissions. Agriculture's main emission sources are N2O from soils and manure management and CH4 from enteric fermentation and manure management. At the same time European forests are a carbon sink mainly due to the fact that European forests are relatively young and by aging sequester carbon. On a global level, however, deforestation appears to be the second largest flux of carbon to the atmospheric pool.

Total EU-25 GHG emissions from agriculture decreased by 14 % between 1990 and 2003. Existing and additional measures are projected to further decrease emissions to 17 and 19 % below 1990 level, respectively. Within the EU-15, emissions of ammonia from agriculture have also decreased by 9% but the sector still provides more than 90 % of total ammonia emissions. In 2003 agriculture contributed 3.6 % of total renewable energy produced and 0.3 % of total primary energy produced in the EU-15.

Changes in manure management systems have a large impact on carbon, CH4 and N2O emissions as well as on water systems. The fertilizer consumption is decreasing, however it is difficult to quantify to what extent this is an direct effect of implementing the CAP decoupling, cross compliance, nitrate directive, water directive, good farming practices or AGRI-environmental measures. It has to be emphasized that there are large uncertainties in emission factors and activity data (organic soils, both N2O and CO2). Between 1990 and 2003 nitrous oxide emissions from agricultural soils fell mainly because of a decrease in the use of nitrogen fertiliser and manure. This can be attributed to a large extent as a consequence of the reform of the EU's common agricultural policy (CAP) and the implementation of the nitrate directive, aimed at reducing water pollution. Carbon losses/emission are still increasing large due to unsustainable agricultural practices leading to land degradation (e.g. decrease in water holding capacity) as well as due to intensive management of Europe's organic soils. At the same time the EU soil thematic strategy is thought to have little impact in the near future unless co-funding from the climate mitigation sector will be available.

The land use sector is a victim be cause ecosystems are vulnerable to climate change even in the light of massive investments into implementation of adaptation strategies. The objective of the United Nations Framework Convention on Climate Change is to ‘‘achieve stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.’’ This level should ‘‘allow ecosystems to adapt naturally to climate change’’. But what is dangerous climate change, and how likely are different amounts of climate change to have major impacts on the world’s ecosystems? In the scientific literature, ‘‘dangerous climate change’’ has often been interpreted in terms of critical levels of climate change or thresholds triggering abrupt climate-change events. However, there is mounting evidence for local ecological responses even to relatively minor climate changes that have occurred during recent decades. Much larger changes, compared with what has occurred already, are projected for the 21st century, yet future climate-change risks for ecosystems have generally been assessed only on qualitative scales, e.g., from ‘‘risks for some’’ to ‘‘risks for many’’ or from ‘‘very low’’ to ‘‘higher’’. For example, a quantitative analysis has been carried out for the global probability of dangerous anthropogenic interference in a coupled social–natural system, which, however, does not involve spatially explicit climate modelling.

Damages due to weather extremes are responsible for a significant share of crop outages and forest decline or large scale disturbances (e.g. fires) in Europe and it is predicted that climate change will increase the share of agricultural/forest losses. Despite of the fact that it has been proven that the climate change signal is real it is still impossible to factor out the climate change signal from the crop losses in Europe which are caused by weather extremes in combination with non-climate change adapted management practices. Assessments on the impact of climate change and possible adaptation strategies have been carried out for agricultural production. However, a consistent approach covering biophysical modelling in combination with economic appraisals on a agricultural/forestry practice level has not yet been carried out. In addition, the effects of climate change induced emergence of weather extremes has also not yet been carried out taking into account possible adaptation strategies.

The changes in land use for climate mitigation alone are projected to be large and will induce competition over different land uses and their implicit goals ranging from improved water management to biodiversity conservation. With climate change kicking in there is mounting evidence from model runs and literature that land competition will intensify indicating that land use policies will become tighter and more complex. Scientific tools will thus have to follow suit and become more integrated in order to reap the benefits of synergies from coordinated policies.

Wider EU Policy Frame

The European Union’s general objective is to move towards a sustainable economy and environment. This general objective is expressed through many initiatives including for example attempts to reduce climate change related hazards through targeted mitigation efforts and reduce vulnerability to climate change through adaptation, participation in international environmental agreements such as the Kyoto Protocol, and the establishment of the European network for global change research (ENRICH). To accomplish the EU’s aspiration to give robust answers to the climate change challenge as well as to respond and continue on the aspirations of the CAP reform substantial changes are necessary in the European agricultural sectors.

Large adoption of agricultural mitigation and adaptation will not only impact the region or country where the adoption takes place but also the rest of the European agricultural and forest sectors. Agricultural and forest commodities are intensively traded within and beyond the European Union. Substantial regional shifts form conventional agriculture to climate change adapted or climate friendly alternative are likely to cause market shifts in all European countries which will finally impact on European land use patters. For example if Brazil will emerge as a primary source for biofuels to the European transport sector Europe will with greater ease be able to implement large integrated water management plans reducing the hazard potential from climate change. On the other hand if Europe decides to produce most of its biofuels with water demanding energy crops domestically clear trade-offs with other environmental goals will emerge and vulnerability to climate change will be increased. Thus, policies at a European scale with trade relationships worldwide can be associated with important market feedbacks. These feedbacks include price and production adjustments. Thus, the scientific tools are necessary to be able to go beyond simple engineering/agronomic assessments of mitigation and adaptation strategies.

Research needs from integrated land use planning

In order to promote integrated and sustainable rural development the CAP reform and other land use policies have to be reinforced by new measures designed to promote a living countryside, to preserve it vigor against climate change and to ensure competitiveness of the farming/forestry sector. The European Climate Change Program has so far mainly dealt with technical mitigation potentials of GHG. A thorough integrated economic and environmental assessment of the economic and sustainable potentials addressing the problem of climate change on farm/enterprise level practices has not yet been carried out. In order to support European agricultural policy the objective should be to develop analytical tool boxes to assess economic and environmental effects of climate mitigation and adaptation on farm levels as well as on the "Land-use Sector" level in an integrated fashion. The approach necessarily must be centered on spatially explicit biophysical assessment of the main bio-geo-chemical cycles integrated with full fledged market modelling. Concise policy conclusions on agricultural practice level from the modelling exercise must be derivable supporting EU policies with special attention of cross-compliance, rural development, sustainable development, and competitiveness issues.

Session 3:

Economic and social implications associated with changes in the water cycle and resources induced by climate change

Impacts on water resources and hydropower production

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The energy sector is affected by climate change through various mechanisms. The most important are:

- Direct effects on the energy production system,
- Direct effects on energy consumption,
- Indirect effects through mitigation/adaptation measures, making greenhouse gas emission neutral production system more competitive than fossile fuel based systems.

Hydropower is generally considered to be a greenhouse gas neutral system, although there are some GHG aspects connected with reservoirs inundating or waterlogging former dry land. Hydropower production systems are influenced by climate change through all mechanisms above, but this presentation will mainly focus on the first effect, i.e. climate change impacts on the resource itself – water availability, and to some extent impacts on system components.

These effects are always important for the operation and future investment planning for the individual hydropower company, and the hydropower sector is one of the economic sectors that has shown most interest in climate change research. To what extent it is important for society depends to a large extent on how important hydropower is for energy supply regionally or on the national level. This varies tremendously through Europe. The highest dependence on hydropower is found in some of the Nordic countries – it constitutes 99% of the electricity production in Norway, 94% in Iceland and 50% in Sweden. Austria gets 63% of its electricity from hydropower, Switzerland 58%, Portugal 38%, Slovenia 31% and Spain 19%. Hydropower has characteristics that makes it particularly valuable in mixed production systems, in particular the low start and stop costs, which makes it very suitable for effect peaking (typically for adjusting diurnal load variations).

Climate change will affect both the total volume of runoff and the seasonal variation. Generally, the effect on total runoff is not clearcut, as total runoff is the difference between precipitation and evapotranspiration, and both are difficult variables to predict under climate change, in particular precipitation. Evapotranspiration tends to increase, while precipitation can go both ways, both with large uncertainties. It is most likely that runoff volume will increase in coastal hydrological regimes, and decrease in continental regimes. In systems where glacier runoff is important, runoff will generally increase, in many cases dramatically, in the short and medium term, and then decrease again, as the glacier covered areas decrease.

Generally, the change in seasonal runoff pattern is easier to predict. In most cases, summer low flow decreases and the low flow period longer, while winter runoff increases. In nival regimes, with present stable winter snow conditions, and perennial spring melt flood, the change in runoff can be dramatic, as illustrated in Figure 1. This shows 30 annual runoff series in an upland Norwegian catchment, presently (upper graph), and after 100 years according to a mainstream climate change scenario. As we see, the winter runoff is dramatically increased, spring melt flood has nearly disappeared, and summer runoff is reduced. In general, variability increases.

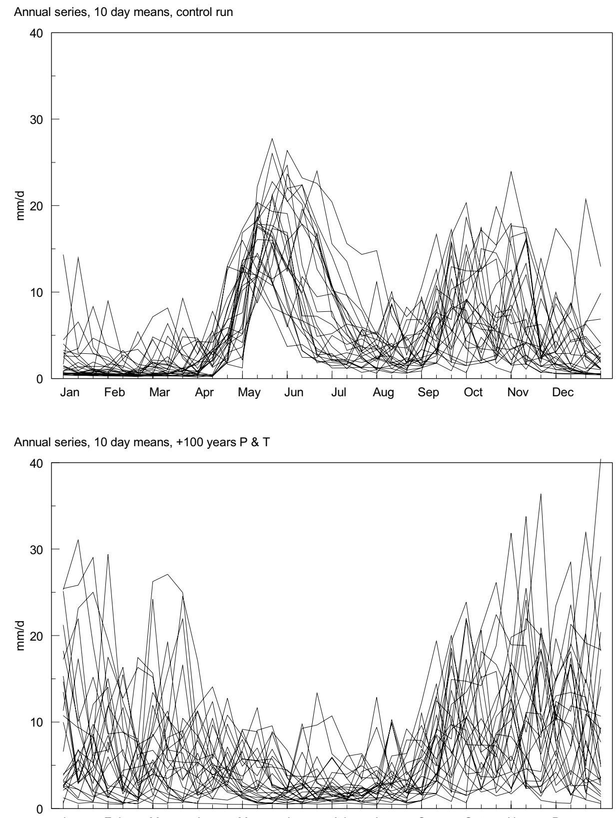

Figure 1 Runoff series in a highland catchment, presently and after 100 years.

Such runoff changes clearly changes the operation of hydropower reservoirs. In the Nordic hydrological regime, as illustrated by Figure 1, the seasonal distribution of the inflow changes towards being more in tune with the consumption, and the result is less stress on the reservoirs, and generally less spill, giving an extra bonus in energy production. This is not necessarily the case in other European hydropower system, and not in systems where glacial melt is a major part of the runoff.

It should be mentioned that the changed operation of the reservoirs may have environmental effects that can be both beneficial and detrimental.

The standard procedures in hydropower operation, investment planning and dam safety considerations has been to rely on historical runoff data, typically 30 or 50 years of data, to represent future reservoir inflow. As we realize that runoff probably is influenced by climate change, this assumption breaks down, and we are faced with a situation where what is certain is that the central data for our planning has become more uncertain. Presently, both our decision systems and the available methods for transforming climate model runs into formal uncertainty estimates are inadequate. Indeed we do not know what is the best estimate of present day annual inflow, nor its uncertainty. A particular concern is dam safety analysis. The present procedures for calculation of design floods for hydroelectric system are based on the assumption that the climate is stable. This is particularly the case for methods based on statistical frequency analysis, while model-based methods are more easily adjusted to a changing climate, once the changes are identified. The problem is we really do not know to what extent the basic assumptions have been compromised by climate change, and the prime worry is not what happens in the future, but what changes have already been invoked. The best way to handle this is probably through increased safety factors, but again – we lack objective methods for handling this.

Session 3:

Economic and social implications associated with changes in the water cycle and resources induced by climate change

Climate change and human dimension: Health impacts of floods

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Climate change affects health status of human populations in direct and indirect ways especially in the context of the World Health Organization definition as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity". [WHO, 1946]

The main focus of this presentation is water related health impact with special attention to floods.

There are essentially four main water-related transmission routes for infections. .

1. Water-borne infections; these occur when humans drink water containing infectious pathogens and consequently develop an infection, for example Cholera and Typhoid.
2. Water-washed infections (also known as water-scarce), are influenced by the quantity of water available. Within this category, we have Scabies and Trachoma.
3. Water based infections is where the pathogen spends its life-cycle in water, such as Schistosomiasis.
4. Water-related insect vector are those pathogens spread via insects which breed in water or bite near water. These include Malaria, Yellow Fever and Dengue.

Occurrence of disease is dependent on three factors, all which may be critically mediated by climate. First, exposure is the extent to which a person is exposed to a climate related hazard such as floods. Second, sensitivity is the extent to which health outcomes are sensitive to climate change. Third, adaptive capacity is the ability of the individual to resist the health effects of climate change.

The vulnerability of an individual to extreme events depends on individual status related to his own health, socioeconomic standing and demographic profile. It will also depend on community level factors such the robustness of community water and sanitation systems; access to information, for example the existence of early warnings and democratic institutions within the community (e.g egalitarian access to water). Another determinant of vulnerability to extreme events is geographical position, for instance the influence of El Niño cycle or disaster proneness. (e.g. population situated in cyclone paths, on earthquake fault lines or in low-lying coastal areas)

Focusing on water related disasters, the presentation emphasized increasing vulnerability to natural disasters which have in last 30 years have increased from less than 100 to a little more than 400, representing a four-fold increase. Natural disasters result in immediate deaths and injuries and nonspecific increases in mortality and break outs of infectious and vector-borne diseases. The affected community can be exposed to toxic substances and develop problems with mental health. Flooding has experienced the greatest increase in the last decade, consequently, the greatest number of people have been affected. However, the impact of disease has been undocumented due to vector and environmental change. In the last 30 years, 2,156 floods were reported in EM-DAT project, resulting in the death of 206,303 people and affecting more than 2.6 billion. Furthermore, flooding causes extensive damage to infrastructure and crops. The affected area is usually immense, but this depends on topographical features.

Similarly, 1,864 windstorms have occurred in the last 30 years, causing the death of 293,758 individuals and affecting more than 557 million people. These are the most destructive disasters covering a wide area and causing significant deaths, injuries, agricultural and property loss. On average, each windstorm has affected close to 300,000 people,

Finally water scarcity, droughts and famines are frequent in many regions but tend to be seasonal. Higher temperatures (i.e. droughts) favour micro-organism proliferation and an increase in gastrointestinal infections whereas Scarcity promotes low sanitation practices leading to skin diseases, infections.

In conclusion the presentation summarized the main barriers to measuring the impact of climate change. Not enough field studies have been carried out which signifies missing data or errors in data, simplified relationships, preconceived notions, inappropriate spatial or temporal data and uncertainty about predictive ability of scenarios.

SESSION IV

ADAPTATION NEEDS OF WATER RESOURCES MANAGEMENT IN EUROPE

Session 4:

Adaptation needs of water resources management in Europe

The session provided key elements on the following issues:

- The current adaptation policy at EU level. The progress on the drafting of a European Commission Green Paper on Adaptation was summarised.
- Adaptation challenges were indicated such as: uncertainty, irreversible losses, involvement of different stakeholders, allocation of costs, cost-effectiveness measures, mal-adaptation, and economic, ethical and political considerations.
- Existing initiatives focus on disaster preparedness. The following key issues in the water sector were highlighted:
    - more research is needed for modelling and cross-sectoral cooperation,
    - implementation of the Water Framework Directive (2000/60/EC) is a key element that could also be used in other sectors,
    - the importance of stakeholder involvement,
    - the integration of adaptation into EU policies, pricing schemes and demand management issues.
- Sustainable management of water resources cannot be achieved unless current water management regimes undergo a transition towards more adaptive and flexible water management.
- Mitigation is needed but it requires long-term action at global level. Adaptation reduces vulnerability to changes at local and regional levels. However, mitigation and adaptation and their impacts are sometimes in conflict.

Session 4:

Adaptation needs of water resources management in Europe

Green Paper on Climate Change and Adaptation Measures

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The climate in Europe is changing; temperatures have risen by 0.8ºC in Europe since records began, and climate models indicate that an increase of temperatures between 2 and 6.3ºC above 1990 levels can be expected by 2100. Precipitation patterns have also varied; annual precipitation over Northern Europe has increased by between 10 and 40% in the last century while the Mediterranean basin has experienced up to 20% reduction in precipitation. Extreme weather events (heat waves, droughts, floods) can be expected to occur more frequently throughout Europe. According to the Association of British Insurers, annual costs from flooding in Europe could increase to 100-120 billion € by 2080.

The European Commission has been addressing the climate change challenge through the European Climate Change Programme (ECCP). The first phase of the ECCP focused on addressing Member States' contribution to climate change, and sought to assist them in reducing their greenhouse gas emissions. In February 2005, the Commission's Communication *Winning the Battle against Global Climate Change* stressed the importance of adaptation to the adverse impacts of climate change. In Europe, only selected policies linked directly to the impacts of climate change have already been put in place: The European Flood Alert System and the European Forest Fire Information System are examples of initiatives seeking to provide early flood warnings and forest fire information. More recently, the European Action Programme on Flood Risk Management has been created, seeking to improve information exchange, encourage better use of EU funding tools (EXCIFF and EXCIMAP), and presenting a proposal for a new legal instrument (directive) on flood risk management.

As part of the second phase of the ECCP, a workgroup was set up to consider how to address the challenge of adaptation to the unavoidable impacts of climate change in Europe. The workgroup sought the views of European Stakeholders on a series of 10 individual sectors, including one on the water cycle, water resources management and the prediction of extreme events, and one on coastal zones, marine resources and tourism. The discussions held at these meetings were aimed at defining the EU role in adaptation policies so as to integrate adaptation fully into relevant European policy areas and identifying good, cost-effective practice in the development of adaptation policy.

The discussions held during these two specific meetings highlighted the challenges ahead for these sectors. Climate change impacts affect local or regional areas, and consequently, decisions for adaptation measures vary by geographic location. The EU may have a role in setting up a European Framework to ensure coordination at the European level between the approach taken to freshwater and coastal waters. The EU must also ensure all key stakeholders, including from other sectors such as agriculture, land-use planning, fisheries,

biodiversity, tourism, human health, etc) are engaged with, as many response strategies target mostly the water sector itself.
Integrated water resources management can be the general framework in which climate adaptation is addressed for the water sector. Therefore, a number of water and marine resources related policies at the EU-level would need to take account of climate adaptation. (Water Framework Directive, Flood Directive, Maritime Policy Green Paper, Integrated Coastal Zone Management…). Further reflection on pricing schemes and demand-management issues, including metering of water use, is required, including on the necessity for these to ensure mal-adaptation is avoided. Research in relation to water and climate change should be pursued; including the need for higher resolution integrated modelling.

The Commission is in the process of producing a Green Paper on adaptation in Europe, listing a set of recommendations in this field, to be published for consultation with European Stakeholders in December 2006.
The Green Paper will address how the commission should share the existing information and bridge the gaps identified on adaptation knowledge in Europe. It will also consider existing EU policies and their suitability in influencing national, regional and local decision-makers implement adaptation planning measures.

The green paper will furthermore be exploring the role of the Commission in the adoption of economic instruments aimed at encouraging climate-resilient investments. Climate change risks and disaster management will also be addressed through recommendations on the introduction of early warning systems and tools to assist in the recovery phase.

The Commission will present the Green Paper and open a debate on the way forward for Adaptation in Europe during a Conference on the 1st December 2006 in Brussels. Three workshops will be organised as part of the consultation process and held in December throughout Europe where reactions to the green paper will be collected from stakeholders.

Session 4:

Adaptation needs of water resources management in Europe

Adaptive Water Management as a response to cope with Implications of Climate Change

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Water management has been successful in the past in securing the availability of water related services and protecting society from water related hazards through technical means. Rather than adapting to periodic variability in water levels (i.e. flooding), the approach has been to control rivers to provide for hydropower production or shipping. The control approach can reach its limits in upland rivers that experience extreme weather events. For example, channelled rivers with high rainfall can have severe floods and there has been an observed increase in damage since people began settling in vulnerable areas such as flood plains. However, once high risk areas are settled, economic investments and assets need to be protected from natural disasters, despite the fact that land use should have been originally restricted. Reliance on engineered infrastructure for protection against water related hazards means that societies have become more vulnerable when this infrastructure fails.

Water quality has been the preliminary focus of improving the ecological integrity of riverine ecosystems. Consequently, there has been a lack of attention to the structural changes in riverbeds and changes in the spatio-temporal variability of water flows which have a strong influence on habitat diversity and ecological function. The building of reservoirs and the use of hydropower have altered the flow regimes of many rivers resulting in detrimental effects on stream ecology (Pahl-Wostl, 1998; Bergkamp et al., 2000). Efforts are being increasingly undertaken to restore the ecological integrity and functions of river basin ecosystems by focusing on the structural properties of river and ecosystem flow requirements. The growing awareness of complexities, unexpected consequences of management strategies and an increase in uncertainties have triggered critical reflection about prevailing water management paradigms (Pahl-Wostl, 2006b).

In the Alpine region for example, climate change will have pronounced impacts on the hydrological regime of many watersheds. Consequently, the water sector has serious challenges ahead, in particular the management of extreme climate conditions. In summer, water shortages are expected due to decreasing precipitation, the increased likelihood of drought periods, an increase in the probability of low-flow conditions (decline of natural buffering capacity due to retreat of glaciers and snow fields) and an intensification of water demand for irrigation. This will have undesirable consequences for water temperature and quality. Due to the increased likelihood of winter and spring floods, there will be increasing demand to use reservoir storage for flood prevention. Overall, a request from downstream areas for balancing water flows to buffer extremes (floods and droughts) is expected. Such requests will require negotiations about changing use priorities and potential trade-offs in reservoir and flood management. Given the considerable uncertainties in climate change predictions it will be important to develop more robust, flexible and adaptive management strategies (Gleick, 2003; Mönch et al, 2003; Kabat and van Scheick, 2003; Pahl-Wostl, in press).

New approaches are currently explored in the NeWater project on Adaptive Water Management Under Uncertainty (www.newater.info). NeWater develops new methods for integrated water management taking into account the complexity of the river basins to be managed and the difficulty in predicting the factors influencing them, e.g., climate, socioeconomic developments. NeWater focuses, in particular, on the transition from current regimes of water management in a river basin to more integrated, adaptive approaches. Adaptive management is needed as a systematic process for improving management policies and practices by learning from the outcomes of implemented management strategies. The whole adaptive management process (see Figure 1) requires a number of steps that are part of an iterative policy cycle:

- In the definition of the problem different perspectives need to be taken into account in a participatory process.
- The design of policies should include scenario analyses to find strategies that perform well under different possible future developments and to identify key uncertainties.
- Decisions should be evaluated by the costs of reversing them.
- The design of monitoring programmes should include different kinds of knowledge to become aware of undesirable developments at an early stage.
- The management cycle must include institutional settings where actors assess the performance of management strategies and implement change if needed.

The implementation of such a management approach is only possible if certain structural conditions are fulfilled. Hence the implementation of adaptive management needs integrated system design.

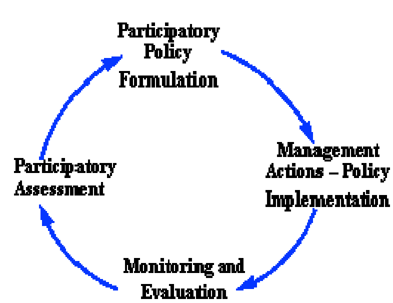

Figure 1. Iterative policy cycle

Which features of a management regime render it more adaptive to maintain environmental, economic and social sustainability in a fast changing and uncertain world? Some structural requirements for a system to be adaptive have been summarized in the following table. Two different regimes are contrasted as the extreme, opposing ends of six axes in Table 1.

Dimension	Prediction, Control Regime	Integrated, Adaptive Regime
Governance	Centralized, hierarchical, narrow stakeholder participation	Polycentric, horizontal, broad stakeholder participation
Sectoral Integration	Sectors separately analysed resulting in policy conflicts and emergent chronic problems	Cross-sectoral analysis identifies emergent problems and integrates policy implementation
Scale of Analysis and Operation	Transboundary problems emerge when river sub-basins are the exclusive scale of analysis and management	Transboundary issues addressed by multiple scales of analysis and management
Information Management	Understanding fragmented by gaps and lack of integration of information sources that are proprietary	Comprehensive understanding achieved by open, shared information sources that fill gaps and facilitate integration
Infrastructure	Massive, centralized infrastructure, single sources of design, power delivery	Appropriate scale, decentralized, diverse sources of design, power delivery
Finances and Risk	Financial resources concentrated in structural protection (sunk costs)	Financial resources diversified using a broad set of private and public financial instruments

Table 1 - Contrast between “prediction, control” and “integrated, adaptive” regimes

The characteristics of integrated adaptive regimes are to be regarded as working hypotheses since the change towards more adaptive regimes is yet slow and empirical data and practical experience thus limited. One possible reason for this lack of innovation is the strong interdependence of the factors stabilizing current management regimes. One cannot, for example, move easily from top-down to participatory management practices without changing the whole approach to information and risk management. Hence, research is urgently needed to better understand the interdependence of key elements of water management regimes and the dynamics of transition processes in order to be able to compare and evaluate alternative management regimes and to implement and support transition processes if required.

However, adaptive management in relation to climate change is limited in prevailing designs, practices and ideas surrounding river basin management. Addressing impacts of climate change may trigger processes of social learning and support a reframing of issues of river basin management to shifting for example the focus from flood management to a wider basin management view that includes storage and buffering of flow and capacity upstream and takes into account ecosystem services.

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Session 4:

Adaptation needs of water resources management in Europe

Climate change impacts on water management and adaptation needs in Europe

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1. Introduction

In the global system, everything is connected to everything else. The climate and freshwater systems are interwoven in a complex way, so that any change in one of these systems induces a change in the other.

All hydrological processes are affected by climate change. Variables of primary importance in water management, such as river discharges, and water levels in rivers, lakes, and ground; and soil moisture are determined by the climate-driven precipitation, evaporation (dependent on climate-driven temperature, radiation, humidity, and wind speed) and snowmelt.

2. Climate change impacts on water availability

There has been an increasing body of evidence of the ongoing global warming. A discernible warming has been observed during 20th century, with higher rate in the last quarter of century. Eleven of the last twelve years belonged to the top twelve globally warmest years in the 165-year observation period. The future warming depends on scenarios of the socio-economic development and on the mitigation policy (curbing the greenhouse gas emissions). Different climate models, and for different scenarios, foresee that the global mean temperature in 2100 will be 1.0 to 6.3 ^{o}C warmer, compared to 1980-1999.

Long-term trends in precipitation have also been observed in many regions. Projected precipitation changes differ regionally, yet are model- and scenario-specific and loaded with high uncertainty. The presently dry areas are likely to become drier, and those presently wet - wetter. Mean annual precipitation is likely to decrease over much of Europe (in particular, over the Southern and the Central Europe) and increase in the North. However, intensity of rainfall events is projected to increase even in regions where the mean annual precipitation is likely to decrease. Changes in extremes are likely to be more dramatic than in the means. Climate change may cause increase of summer drying in continental interiors. Semi-arid and arid areas are particularly exposed: in much of Southern Europe, a joint effect of temperature rise and precipitation drop is foreseen for the summer.

Ongoing climatic and non-climatic changes have already influenced water resources in a discernible way and even stronger changes are projected for the future. The most certain impacts of climate change on freshwater systems are due to the increases in temperature, sea level and precipitation variability. There are generally consistent patterns of change in water availability – increases in high latitudes and decreases in mid-latitudes. Where changes in temperature produce changes in the timing of streamflow, climate change effects are generally stronger than in areas, where hydrological regimes are more sensitive to changes in precipitation. Warming leads to changes in seasonality of river discharge in catchments where much winter precipitation falls as snow (e.g. in the Alps); winter flows increase, with peaks coming earlier, and summer flows decrease. Ongoing reduction of European glaciers will lead to gradual decrease of glacier contribution to river discharge. Decreasing groundwater recharge is projected over many areas, also in already water-stressed regions. Hence, the possibility to offset declining surface water availability due to increasing precipitation variability may not be practical. Sea level rise will extend areas of salinization of groundwater and estuaries, resulting in a decrease of freshwater availability for humans and ecosystems.

In much of Europe, occurrences of a very wet winter and of an intense rainfall event will become more frequent, with likely consequences to flood risk. Increasing temperature and variability in runoff are likely to lead to adverse changes in water quality (turbidity increase, algal bloom, mobilizing and washing away pollutants, pathogens, and thermal pollution).

The negative impacts of climate change on freshwater systems outweigh its benefits. Areas in which runoff is projected to decline are likely to face a clear reduction in the value of the services provided by water resources. The beneficial impacts of increased annual runoff in other areas will be tempered by negative effects of increased precipitation variability.

Adverse effects of climate on freshwater systems exacerbate impacts of other stresses, such as population pressure, economic growth, and land use change (including urbanization). Globally, water demand will grow in the coming decades primarily due to population and economic growth, but regionally, large changes in irrigation water demand as a result of climate changes are likely.

Despite the progress in evaluating uncertainties (e.g., in ensembles-based studies), quantitative projections of changes in precipitation, river flows and water levels remain largely uncertain, with main sources of uncertainty being: scenarios, climate models, downscaling, hydrological models, available data.

3. Adaptation: notions and concepts in water management perspective

A definition of adaptation accepted in the IPCC process is: adjustment in natural or human systems in response to actual or expected climatic *stimuli* or their effects, which moderates harm or exploits beneficial opportunities. Taxonomy of adaptation distinguishes several classification into adaptation types (dichotomies), such as: anticipatory (proactive) or reactive; autonomous (spontaneous) or planned; private / public, etc.

Management decisions are always made on the basis of uncertain information. Adaptation, both reactive (to ongoing changes) and anticipative (to projected changes) makes use of a feedback mechanism, implementing changes (and possibly correcting past mistakes) in response to new knowledge and information (from monitoring and research).

Capacity to adapt largely varies across regions, societies and gender and income groups (differences being based on a number of factors, such as wealth, housing quality and location, level of education, mobility etc.) Enhancing adaptive capacity is needed i.e. increasing system’s coping capacity and coping range.

Adaptation policy stakeholders are manifold, from central via regional to local authorities, individuals and communities affected or threatened, planning bodies, NGOs, researchers and the media. Participatory decision making is indispensable in the adaptation process. Central governments may create enhancing environment. Mainstreaming should be sought, based on integration of adaptation strategies, which become part of national or regional development policies.

The water resources have always been distributed unevenly in space and time and the Man has tried to adapt to this unevenness and smooth the spatial-temporal variability. Regulating flow in time to suit human needs can be achieved by storage reservoirs (capturing water when abundant and using it when it is scarce), while regulating flow in space can be achieved via water transfer.

There are several adaptation strategies in the area of coping with floods, which can be labeled as: protect, accommodate, or retreat (relocate). Strategies for flood protection and management may modify either flood waters, or susceptibility to flood damage and impact of flooding. The EU Floods Directive deals with a roster of adaptive measures, such as risk assessment ("taking into account long-term development including climate change"), risk maps and management plans. In some countries, such as the Netherlands and the UK, flood design values have been increased, based on early climate change impact scenarios.

There can be limits to adaptation, therein physical limits (e.g. when rivers dry up completely, becoming ephemeral); economic limits (affordability; cost – benefit and cost – efficiency thresholds); socio-political limits (constructing water storage reservoirs may not be acceptable due to the detrimental effects to the environment and the need for resettlement) unpalatable enforcement of reduced reliability or standard of service); or institutional limits (e.g. inadequate capacity of water management agencies), cf. Arnell & Delaney (2006).

Barriers to adaptation to floods via relocation can be external, e. g. lack of land for relocation, or internal, such as unwillingness of people to relocate.

4. Adaptation to climate change in water management

Adaptation to changing conditions has always been the core of water management. However, in the past water management focused on meeting the ever increasing demand. Climate changes cause changes in both water supply and water demand and challenge the existing water management practices by adding uncertainties. Climate change poses novel risks often outside the range of experience.

Both mitigation of climate change and adaptation to climate change are needed to avert or reduce adverse impacts. Adaptation strategies can reduce vulnerability to changes in climate at the local and regional level. Mitigation acts on a global level over longer time scales due to the inertia of the climate system, slowing the rate of climate change and thus delaying the date of impact and its magnitude. Most of the benefits of mitigation will not be realised until several decades later, thus adaptation is needed to address near-future impacts. However, without mitigation, the increasing magnitude of climate change would significantly diminish the effectiveness of adaptation.
Mitigation of climate change and adaptation to climate change and its impacts are sometimes in conflict. For instance, desalination serves adaptation, but requires high energy input, hence adversely affecting mitigation - it drives the atmospheric greenhouse gas concentration and warming. Afforestation serves mitigation (carbon sequestration) but may play adverse role in

adaptation (transpiration of large amounts of increasingly precious water). Enhancing water storage in reservoirs brings co-benefits, being advantageous for both mitigation (hydropower without fossil fuel burning) and adaptation (weakening hydrological extremes – floods and droughts).

Adaptive capacity can be increased by co-ordinating adaptation strategies (via so called "mainstreaming") into development policy planning at the global, EU, regional, national, sub-national, or sectoral level.

In general, Europe has a high adaptation potential in socio-economic terms due to strong economic conditions, high GDP, stable growth, stable, well-trained population with capacity to migrate within the super-national organism of the EU, and well developed political, institutional, and technological support systems. However, adaptation is generally low for natural systems. Also, equity issues come about, since more marginal and less wealthy areas (and groups of people within an area) are less able to adapt.

Table 1 presents a roster of adaptation options addressing water-related problems exacerbated by climate change. It refers particularly to increasing variability of water resources, i. e. increase frequency of occurrence of the state of having too little water and having too much water. Adaptation options for the former situation address water supply side or water demand side. Adaptation for the latter situation addresses options aimed at reduction of the load or increase of resistance.

Table 1 – Adaptation options addressing water-related problems exacerbated by climate change

Water-related problem exacerbated by climate change	**Adaptation options**	
Too little water (water stress, drought)	Supply side – enhance water supply	Desalination of sea water Conjunctive use of surface water and groundwater Increased storage capacity for surface water, groundwater & rain water Water transfer Removing of invasive non-native vegetation
	Demand side – reduce water demand	Improving efficiency of water use (e.g., „more crop per drop" in irrigation; recycling water; re-use after treatment of waste water) Water demand management through metering, promoting water saving technologies Leak reduction Soil moisture conservation e.g. through mulching. Market-based instruments, e.g. water pricing Re-allocation of water to high-value uses Awareness raising
Too much water (intense precipitation, flooding)	Reduce load	Enhanced implementation of structural (technical) protection measures (dikes, relief channels, enhanced water storage) Watershed management "to keep water where it falls" and reduce surface runoff and erosion
	Increase resistance	Flood forecasting and warning Regulation through planning legislation and zoning Flood insurance Relocation of population living in flood-risk areas

Some adaptation measures can be „no-regret" but typically they entail significant costs. However, estimates of costs and benefits of adaptation (in terms of damages avoided) are limited and rather speculative. This area constitutes a clear research need.

Early adaptation is effective for avoiding damage, provided that projections of future climate change are sufficiently accurate. Delayed adaptation may lead to greater subsequent costs. However, rue to climate change uncertainty, water managers can no longer have confidence in single projections of the future. The large range for different climate model-based scenarios suggests that adaptive planning should be based on ensembles (cf. ENSEMBLES Project web page). It is difficult to evaluate the credibility of individual scenarios.

5. Concluding remarks

Except where land-use change occurs, it has been assumed that the natural resource base is constant. Traditional assumption in hydrological design is the one of stationarity: the past is the key to the future. Since this assumption is incorrect, there is a need to revise the current design procedures, but the existing climate projections for the future are loaded with high uncertainty. Current water management practices are very likely to be inadequate to reduce negative impacts of climate change on water supply reliability, flood risk, health, energy and aquatic ecosystems.

Many potential current adaptations are consistent with sustainable development; that is, they can protect against both climate variability now and future climate change (this refers in particular to „no-regret" strategies – doing things that make sense anyway. It is always good to save energy and water). Improved incorporation of current climate variability into water-related management would render societies better prepared to future climate change.

Acknowledgements The author is grateful to his fellow colleagues co-authoring Chapter 3 (Freshwater resources and their management) of the Fourth Assessment Report of the Intergovernmental Panel on Climate Change Working Group 2 (Kundzewicz et al., 2007), who have considerably influenced his opinion. Part of the material reported in this paper is a background activity in the ENSEMBLES and ADAM integrated projects of the 6 Framework Programme of the EU.

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SESSION V

CLIMATE CHANGE AND THE WATER DIMENSION IN THE MS: RESEARCH AND POLICY

Session 5:

Climate change and the water dimension in the MS: research and policy

The session provided key elements on:

- Threats due to climate change include sea level rising, growing risks of flooding, increasing winter rainfall, droughts, land subsidence, increased severity of storms, increased river water levels, etc.
- The Water Framework Directive (2000/60/EC) provides a framework for adaptation measures within RBMP cycling. The review cycle opens the way for adaptation strategies but this will not solve the problem in other sectors that should be involved (transport, tourism, agriculture, etc.)
- The integration of climate change strategy includes different socio-economic sectors and ecological systems. This is linked to knowledge generation and capacity-building.
- Climate change will cause a decrease in water resources of 5 to 14% by 2030, 17% by 2060 and 20-22% by the end of the 21st century.
- The strategy is a combination of top-down (emission scenarios → vulnerability (physical)) and bottom-up (adaptive strategy → vulnerability (social)) approaches from a global to a local scale.
- A key element is the participation of all stakeholders.
- Temporal horizons vary among sectors. Education and public awareness are also key in planning strategies.
- There is a need for a clear framework at EU level to assist local, regional and national decision-making. Current financing and compensation mechanisms may prove to be inappropriate: long-term quality issues have to be evaluated.

The workshop was closed by the Director-General of the Directorate-General for Research, Mr. José Manuel Silva Rodriguez.

Session 5:

Climate change and the water dimension in the MS: research and policy

Introduction to national adaptation strategies for climate impacts on water resources in the EU

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Climate change in Europe

Temperature in Europe has over the past century increased faster than the global average. Large temperature increases have been observed over the Iberian Peninsula, South-Eastern Europe, North-western Russia, and the Baltic states, with the largest increases in the arctic regions. The global average temperature is projected to increase 1.5-5.8 °C during this century. The European average temperature is projected to increase 2.1-4.4 °C by 2080, with the highest increases in Northern Europe and the Mediterranean region. In Northern Europe the largest warming is projected in winter, while the warming in central and Mediterranean Europe is projected to peak in summer. Europe has experienced over the recent decades an increase in heat waves, while the number of cold extremes decreased.

The annual precipitation in Europe increased 10-40% during 20th century in Northern Europe while Southern Europe became up to 20% dryer. Precipitation projections for Europe vary between climate models and scenarios. The annual mean precipitation is projected to increase in Northern Europe, especially in winter, and decrease further south.

Projections for temperature and precipitation extremes are highly uncertain. In most models and scenarios warm periods are projected to be more intense, more frequent and longer lasting. The probability of extreme precipitation events is projected to increase in western and northern Europe, whereas many parts of the Mediterranean may experience further reduced rainfall and longer droughts periods.

Water resources and climate change

In Europe there are many different hydrological regimes. In the south, there is a large seasonal variation in river flow due to wet winters and long and dry summers. In North-western Europe river flow remain reasonably constant throughout the year. In the north and east and in mountainous areas, much precipitation falls as snow and maximum river flow occurs during the snow melting period in spring.

In addition there is also a wide variety of pressures from human activities on water resources across Europe. The pressures are from multiple usage (e.g. fisheries, navigation, and water abstraction), nutrient enrichment and organic pollution from industry, agriculture and other sectors and alterations of the hydromorphological characteristics. A succession of floods and droughts in recent years has illustrated Europe's vulnerability to hydrological extremes.

Climate change is an additional pressure and already has an impact on European water resources and management, and is expected increasingly to be so in future. In south-eastern

Europe annual rainfall and river discharge has decreased in the past few decades. Climate change may change the timing and magnitude of both high flows and low flows. The occurrence of greatest flood risk could move from spring to winter, and be enhanced by the expansion of impermeable surfaces due to urbanization.

In addition to direct effects on, for example, precipitation and hydrological regimes, climate change also significantly influences other pressures on the quantitative and qualitative status of water bodies. Temperature rise and changing precipitation patterns may lead to a reduction of groundwater recharge and hence groundwater level, perhaps most severely in southern and south Eastern Europe. At the same time, these same climate change induced factors increase the demand for the resource, thus adding to the pressure.

Various scenario studies indicate that water availability is projected to increase in northern and north-western Europe and decrease in southern and south-eastern Europe. Changes in water demand strongly depend on economic growth and societal development. In Western Europe under some scenarios, withdrawals would be decreasing due to saturation of demands and increasing efficiency of water use. In Eastern Europe economic growth would lead to increasing demands for water in both the domestic and industrial sectors. In the agricultural sector, irrigation water requirements would increase mainly in southern and south Eastern Europe.

Higher water temperatures and lower river flows in summer can lead to deterioration of water quality and the status of water bodies. In contrast, increases in extreme rainfall events and flash flooding will increase pollution from diffuse sources (such as agriculture) and the risk of point source pollution from, for example, storm water overflow and emergency discharges from waste water treatment plants.

EU Water Framework Directive

Directive 2000/60/EC Establishing a Framework for Community Action in the Field of Water Policy (the Water Framework Directive – WFD) entered into force on 22 December 2000. The objective of the WFD is to establish a framework for the protection of inland surface waters, transitional waters, coastal waters and groundwater which: (a) prevents further deterioration, protects and enhances the status of aquatic ecosystems and the water needs of terrestrial and wetland ecosystems; (b) promotes sustainable water use based on the long-term protection of available water resources; (c) enhances protection and improvement of the aquatic environment; (d) ensures the progressive reduction of pollution of groundwater; and (e) contributes to mitigating the effects of floods and droughts.

A significant shift from the previous regulatory regime is that ecological status is now the key means by which water quality will be assessed. The WFD provides definitions of what constitutes “high”, “good” and “moderate” ecological status for rivers, lakes, transitional and coastal. The core concepts and definitions can be summarised as:

- the ecological status of waters is defined by the structure of the biological communities that would be expected to be in existence in the absence of anthropogenic impacts;
- ‘good’ status permits slight changes from what would be expected given the above, where these are expected because of anthropogenic impacts; and
- the hydromorphological and physico-chemical parameters are consistent with the above.

- The definitions are wide in scope because they must reflect the differences between water bodies and catchments in terms of, for example, their hydrology, geology, soils, flow rate, substrates, and the different biological communities that occur (or would be expected to occur in the absence of anthropogenic impacts).

The Directive requires that Member States must achieve Good Ecological Status in water bodies by 2015. To achieve the objectives in Member States, the WFD puts in place the concept of River Basin Management Planning (RBMP), the objective of which is to permit the identification and control of (anthropogenic) pressures likely to be inconsistent with the achievement of Good Ecological Status.

There are several requirements on what is to be contained in RBMPs:

- the characteristics of the river basin;
- environmental monitoring data;
- analysis of the impacts of human activity (point and diffuse pollution, abstractions, etc.);
- the economic usage of water; and
- a strategic plan for the achievement of good status, where this requires the identification of a programme of measures.

To achieve the target of Good Ecological Status by 2015, a timetable of stepwise implementation is provided for in the WFD. To date, Member States should have completed core work including:

- Article 3 reports covering competent authorities for each district; and
- Article 5 reports covering the characteristics of the river basin districts, review of the environmental impact of human activity and economic analysis of water use.

The remainder of the core parts of the implementation timetable are as follows:

- publish and consult on an interim overview of significant water management issues for each river basin district (Article 14 – by 22 December 2007);
- publish and consult on drafts of the river basin management plans (Article 14), establish programmes of measures in each river basin district in order to deliver environmental objectives (Article 11) (by 22 December 2008)
- publish first river basin management plan for each river basin district, including environmental objectives for each body of surface or groundwater and summaries of programmes of measures (Article 13 - 22 December 2009);
- make operational programmes of measures in each river basin district to deliver environmental objectives (Article 11) (by 2010);
- interim progress reports to be prepared on progress in implementing planned programmes of measures (Article 15 – by 22 December 2012);
- main environmental objectives to be met (Article 4 – by 22 December 2015);
- review and update plans (by 22 December 2015 and every six years thereafter).

Climate Change and the Water Framework Directive

Because climate change has important and significant implications for future water resources it also has significant implications for the ecological status of water bodies. This also means that climate change has important implications for preventing deterioration and enhancing ecological status of water bodies, and all of the other core objectives set out in Article 1 of the WFD. Thus, while the timing of the negotiations on the WFD has meant that the term 'climate change' does not appear in the WFD, there is a need to consider climate change within the scope of the ongoing process of implementing the Directive.

The structure, processes, objectives and timetable of the WFD provides a number of opportunities to incorporate the Climate Change considerations that are not only necessary to the achievement of the Directive's core objectives, but also for the future needs of society and the environment. Ideally, the consideration of climate change should be fully integrated into the work programmes that culminate in RBMPs and the making of programmes of measures operational in each river basin district by 2010.

Some links to climate change considerations already exist within the WFD Common Implementation Strategy Guidance (CIS Guidance) documents of which there are over 20. For example:

- *Guidance Document 3 - Pressures and Impacts* provides an uncompleted list of anthropogenic pressures to consider, one of which is climate change listed under 'other anthropogenic impacts';
- Annex G of *Guidance Document 10 - Rivers and Lakes – Typology, Reference Conditions and Classification Systems* makes references to the need to consider expert input to assess the impact of climate change on water quality

The issue of flooding is specifically addressed in the proposal for a Directive on flood risk management which was published in early 2006. The Directive should provide a vehicle for addressing increased flood risk from climate change, requiring Member States to draw up flood risk management plans for flood risk zones. These management plans should focus particularly on prevention, protection and preparedness measures. Climate change is recognised as one of several factors that might increase the scale and frequency of floods in the future. The proposed Directive requests that projected climate change should be taken into account in the assessment of future flood risk and of its consequences on human health, the environment, and the economy. The proposed Floods Directive includes a number of links to the WFD to ensure close coordination in the two implementation processes, including common administrative units to which RBMPs apply.

The cyclical review process within both Directives allows for a climate change adaptation process that can be reviewed and amended in the light of latest evidence.

National climate change adaptation developments

Some information is available on existing national adaptation strategies and measures based on the EEA report on climate change vulnerability and adaptation (2005) and an initial analysis of EEA member countries' responses to a questionnaire distributed in 2006, jointly with the forthcoming 2007 German Presidency. Several countries have undertaken or are in the process of implementing comprehensive, interdisciplinary, multi-sector national assessments of climate change. However, few Member States have developed and adopted comprehensive National Adaptation Strategies.

Existing adaptive measures are concentrated in flood defence which has enjoyed a long tradition of dealing with climate extremes. Many of the existing adaptive responses have been triggered by the substantial economic losses, and health and ecosystem impacts, from extreme weather events in recent years (e.g. 2002 and 2005 floods and 2003 heat waves and droughts). These measures are often directed at reducing vulnerability to current climate variability and extreme weather conditions and not addressing long-term climate change. Further efforts are required to improve the quality of climate scenario at scales relevant to adaptation, develop methods and tools to reduce and/or better represent uncertainties in climate assessment, and to evaluate, cost and prioritise adaptation options.

Conclusions

There is both a need and an opportunity to integrate climate change adaptation measures in water management into the Water Framework Directive. Because of the cross cutting effects of climate change, the risks posed by climate change should be considered alongside all other pressures and risks in order to achieve the objectives of the WFD.

The six year periodic cycle of the WFD allows for a long-term strategic adaptation process. However adaptation strategies have to include measures in all water related sectors, in particular agriculture, energy, navigation and tourism. Furthermore inclusion of climate change in spatial planning is important. There is need for appropriate attention to demand management strategies, in addition to supply measures.

Session 5:

Climate change and the water dimension in the MS: research and policy

Case study 1: The Spanish strategy: National adaptation Plan to Climate Change

José Ramón Picatoste Ruggeroni,

Head of impacts and adaptation unit in the Spanish CC Office, Ministry for Environment, Spain

The Spanish Adaptation Plan to Climate Change is an initiative of the Spanish Ministry of Environment, which will provide the general reference framework for all the activities related to the assessments of impacts, vulnerability and adaptation to climate change. The main aim of this instrument is to integrate adaptation to climate change into the planning strategy of the different socio-economic sectors and ecological systems in Spain (mainstreaming). It will assist all those administrations and organizations interested – private and public – in evaluating the impacts of climate change in their area of interest, facilitating knowledge, tools and methods, and promoting participation processes focus on the definition of the better options for adapting to climate change.

Spain, due to its geographical situation and socioeconomics characteristics, is very vulnerable to climate change. Recent researches show projections of climate change for the 21st century in Spain, simulated by regional climate models under different emissions scenarios: progressive trend towards an increase in average temperatures throughout the century, significantly greater in summer months than in winter ones, and a generalised tendency towards less annual accumulated rainfall. A project promoted by the Spanish Climate Change Bureau, with participation of more that 400 expert, has compiled the most relevant predicted impacts in the different socioeconomic sectors –including water resources- and ecological systems (*Preliminary Assessment of the Impacts in Spain due to the Effect of Climate Change,* Ministry of Environment, 2005)

Water is a high priority driven sector in Spain: changes in water resources (quality and quantity) have a great and direct effect on many other sectors, particularly on the agriculture, forestry, energy and tourism sectors, on biodiversity, on human health and on natural risks of climatic origin.

Preliminary assessment using incremental scenarios and regional climate scenarios shows that climate change in Spain will cause a decrease in water yields and increased demand for irrigation systems. For the 2030 horizon, we can expect average decreases in hydrological resources in natural regime of between 5 and 14%, whereas for 2060 an average global reduction of hydrological resources is expected of 17% on the Peninsula. The most critical Spanish areas are arid and semiarid ones (aprox. 30% of the national surface), where the resource can decrease up to 50% at the end of the century. Along with this decrease in resources, an increase is expected in the interannual variability thereof. The impact will be noted more severely in the Guadiana, Canarias, Segura, Júcar, Guadalquivir, Sur and Balearic Isles river basins.

The Adaptation Plan to Climate Change was presented last February to the main coordinating bodies for Climate Change in Spain: the Commission for Coordination of Climate Change Policies (CCPCC), the National Climate Council (CNC) and the Sectorial Conference on the Environment. Subsequently, a public consultation process was opened in order to get comments and contributions that were mostly incorporated to the document. Then, the Plan was formally approved in July by CCPCC and CNC and, most recently, the Council of Ministers has taken knowledge of it, which constitutes a very important milestone and provides the necessary political support to develop and implement the Plan.

The Spanish Adaptation Plan to Climate Change has selected several main priority lines of work for its first programme of work, among them:

- Generation of regional climate scenarios

The regional climate change scenarios for Spain are essential for the evaluation of impacts, vulnerability and adaptation to climate change. Hence, it is very important to reach enough scientific, technical and operative capacity, always in progress, which will allow for a continuous generation of climate change scenarios at a regional scale.

- Assessment of the impact of climate change on water resources

The objective is to develop quantitative scenarios of water resources in Spain river basins for the 21st century, to assess the management and capacity of the Spanish hydrological system under these water resources scenarios, to assess the climate change impacts in the water ecological status and to assess the potential climate change effects on irrigation and other demands.

The Spanish Adaptation Plan to Climate Change has as a key element the participation of the stakeholders in all the phases of the assessments. The expected outcome from the assessment of the impact of climate change in water resources is to consider the full range of options available for the adaptation to climate change, in order to integrate the most appropriated of them into the sector planning strategy and tools (mainstreaming in the implementation of the WFD).

More information in:
http://www.mma.es/portal/secciones/cambio_climatico/areas_tematicas/impactos_cc/index.htm

Session 5:

Climate change and the water dimension in the MS: research and policy

Case study 2: UK adaptation strategy in the water sector: approach and issues

Merylyn McKenzie Hedger[1], Rob Wilby[2],

[1] *Environment Agency for England and Wales: merylyn.hedger@environment-agency.gov.uk*
from 16th October 2006 EEA: merylyn.hedger@eea.europa.eu

[2] *Environment Agency for England and Wales: rob.wilby@environment-agency.gov.uk*

Introduction

The UK Government (Defra) is developing an Adaptation Policy Framework (APF) in three phases (Defra, 2005). This strategic approach will identify key risks and opportunities across a number of policy areas, and co-ordinate approaches across departments and other bodies in the public sector (and beyond) who will need to work together. This framework will integrate, particularly in the water sector, a complex picture of existing policy initiatives.

This note describes how policies are already being revised to take account of climate change in two ways. First, existing policy and strategies in are being modified in an incremental way, and secondly responses to extreme events generate some step changes. Both tracks occur within established policy and institutional frameworks, and these frame timescales, research used and the types of economic appraisal undertaken. Innovation, occurs exceptionally around major vulnerabilities and in response to extreme weather events.

Incremental and step changes

Climate change is gradually being factored into key sectoral areas of policy – a process of embedding or mainstreaming. This process began with flood risk management (sea-level rise) following the publication of the first IPCC Assessment in 1990. Since then climate change has been incorporated into more design standards in flood risk management as scientific understanding has grown. Flooding has assumed an increasingly high profile in public policy in the UK. Institutional responsibilities have been changed, investment has been increased in infrastructure and research, more attention is given to preventing development in flood plains and improved warning systems have been introduced. Latest scientific understanding of changes in sea level, peak rainfall intensities, river flows, offshore winds and waves are being translated into allowances for use in spatial planning and engineering design (Defra, 2006).

Climate change was included for the first time in strategic water resource planning in 2004, and serious attention is now being given to water quality and biodiversity strategies. Water resources management in the UK has been experiencing a profound transformation in recent years. There has been a shift in approach from the traditional small scale, site-specific and primarily hard engineering approaches to dealing with drought and pollution problems, to a more strategic, less engineered, holistic approach to 'managing water resources' at catchment scales. This shift reflects developments at European level within the Habitats Directive as well as the Water Framework Directive (WFD, that is delivering River Basin Management Plans RBMPs). More specifically across England and Wales this is being delivered via the production of Catchment Abstraction Management Strategies (CAMS) and Catchment Flood Management Plans (CFMPs) by the Environment Agency. As with flood risk management, standard climate change 'factors' and guidance are being developed, in this case, to support the next round of water plans due in 2009 (Romanowicz et al., 2006).

The process has proceeded in two ways: through gradual incremental change and in response to extreme weather events. Each strategy process has its own policy levers/ issues, time-scales for the decision-making process, players, treatment of costs and climate change (for example see Figure 1 for the process within which Catchment Flood Management Plans sit). Dealing with the climate change dimension of floods and droughts is being embedded within existing policy strategies, in a piecemeal way and depending on the planning cycles of the various components. The incorporation of climate change is itself linked to the latest climate change scenarios available – as in the UK and elsewhere climate models have their own cycles of revision.

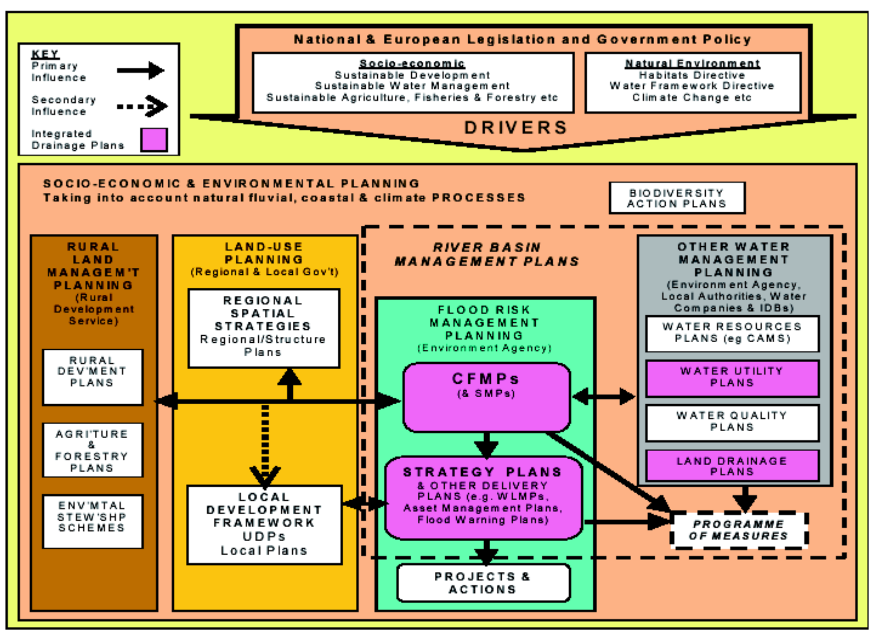
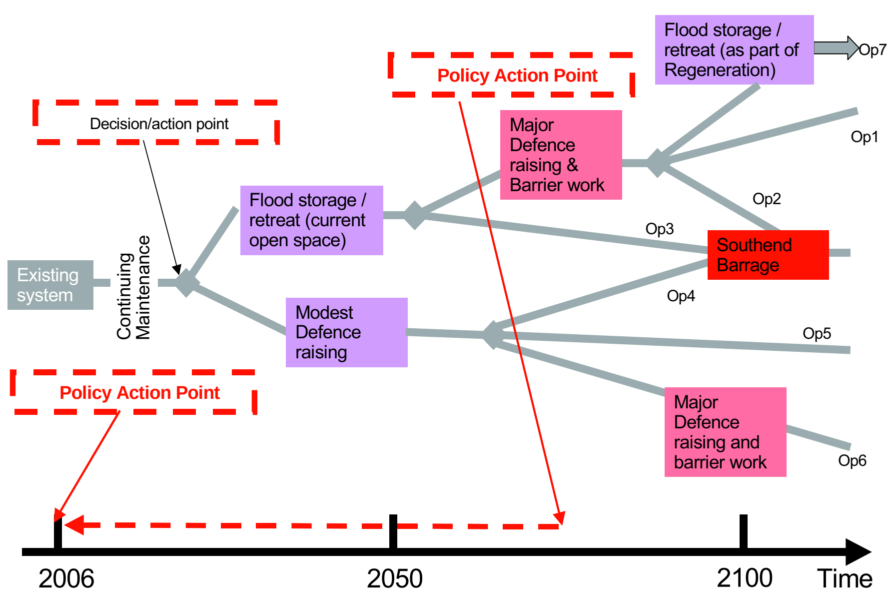


Figure 1 Catchment Flood Management Plans

This process has been interactive with research: key new results have driven policy change and the perceived need to tackle climate change is increasingly pushing the research community to produce hard facts that can be used for design standards. Key levers for change arise with responses and planning for extreme events on a large scale and over long timeframes with significant impacts on lives and property that potentially do allow for changes in assessment methodologies. Obviously early action to reduce impacts through adaptation measures will avoid damages and the need for increased expenditure at a later date. It is also necessary to maintain current levels of protection in a changing climate. And from a societal, institutional and operational perspective we cannot suddenly start adapting to climate change in 30 years time. We need to be on the right adaptation technological and policy development path, just as we strive for the low-carbon economy path.

The Thames Estuary 2100 Project, which is planning to upgrade the flood defences for London, has provided the opportunity to develop new methodologies. The project will produce an adaptive plan for the management of flood risk in the tidal Thames for the century, considering the uncertainty in planning over such a long time and specifically the uncertainty in climate change impacts. This project shows that with a long term, large problem, the full panoply of technical options can be explored: maintenance, modest defence improvement, flood storage land use planning and major investments. Options planning (see Figures 2 and 3) has been used to identify strategic long-term decision pathways in view of the value of the assets and the long-life span of investments. This type of analysis shows that we must identify critical decision-points along a timeframe, now, to identify opportunities for adaptation. Short-term decisions are needed to keep long–term flexibility.



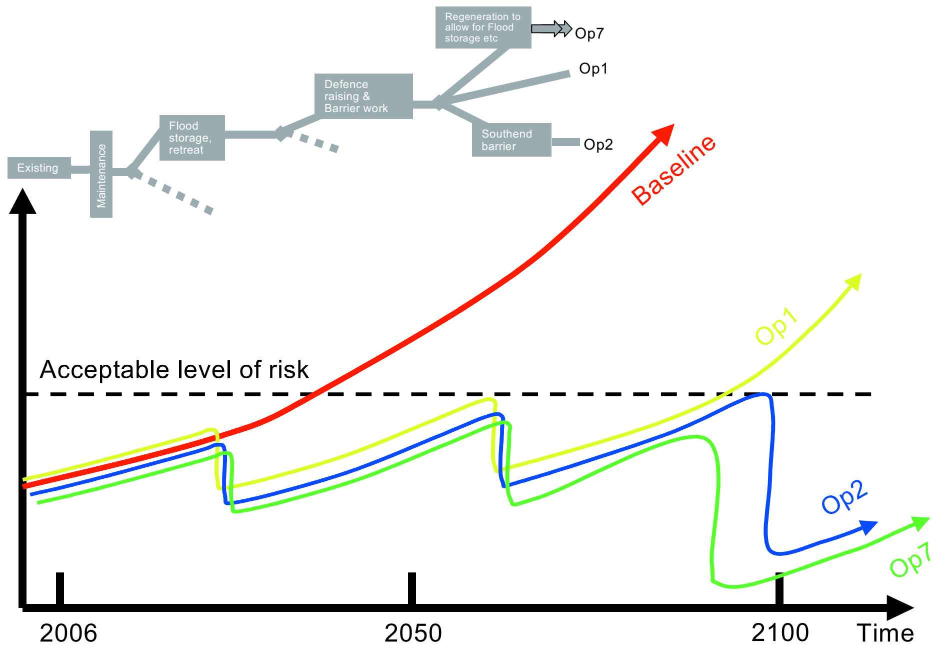


Figure 3. Outcome of different flood defence options. Source: Thames Estuary 2100 Project

Decision-support tools to overcome gaps, have also emerged, notably uncertainty frameworks, and new approaches to regional climate modelling are under development, such as probabilistic approaches (Wilby & Harris, 2006) or accessible statistical tools such as the Environment Agency's Rainfall and Weather Impacts Generator (EARWIG) tool (Kilsby et al., 2006). Probabilistic approaches can help combine uncertainties from a range of sources including emissions, GCMs, downscaling method, impacts model and so on (see Figure 4).

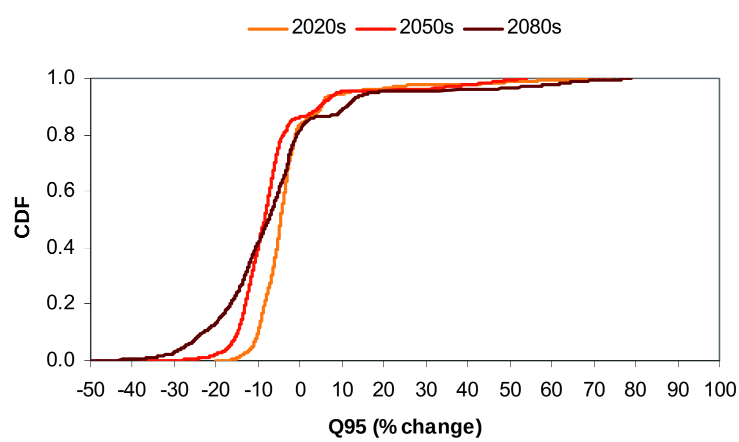


Figure 4. Example probabilistic climate change projections for changes (%) in low flows (Q95) of the River Thames by the 2020s, 2050s and 2080s.

Issues

a. We need a clear, coherent framework for adaptation from European, though to national, regional and local levels.

Currently the best example of an issue for attention is the European Directive on Water Quality (the Water Framework Directive). This was only drafted in 2000 but did not explicitly mention climate change. Moreover it also indicates that major floods and droughts can be treated as exceptional. Nonetheless, the WFD is potentially a useful tool for climate change adaptation policy as it allows for economic appraisal of measures, covers water flows and quality issues, and sets up new systems of River Basin Management Plans, involving local partnerships. It is also cyclical, with 6-year iterations, so provides for revision as understanding increases and uncertainty reduces. The first cycle completes in 2015, when at least projected temperature changes could become a more significant consideration in water quality and biodiversity management.

In the UK we have an active network of regional climate change adaptation partnerships (McKenzie Hedger et al., 2006). Often they are tackling issues at that level which could be resolved or resourced more effectively at a national level. Conversely, issues are also evident at the local level where a clear national framework would help.

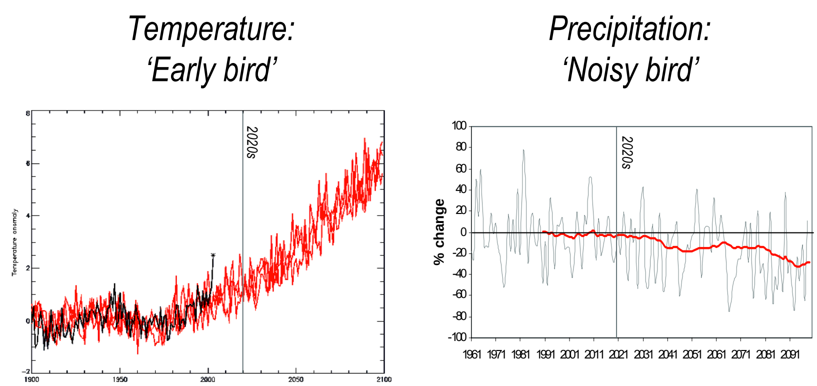
b. Costs fall unevenly across the public and private sectors affecting how incentives are constructed and increasing the possibility of disparities under climate change

Water is now delivered though private companies who charge for water supply and sewerage. But the sector is regulated and subject to other legislation such as biodiversity conservation. In some locations, water abstractions authorised under licences granted years ago are causing environmental degradation. There are some 600 sites where current licensed abstraction is thought to be causing problems, or has the potential to do so under current conditions (such as damage to fish stocks). Dealing with these damaging abstractions will be expensive. Under the EU Habitats Directive we have reviewed consents. The Agency believes that up to £480 million in compensation could be payable to licence holders if their licences have to be revoked or modified. But if a climate change lens is put on some of this expenditure – such as the protection of salmon in rivers in southern England (Environment Agency, 2005) – these may not be sensible investments that yield sustainable environmental benefits.

Elsewhere, expenditure on flood defence schemes (financed mostly by central Government and some local levies) has to provide compensation when habitats are affected. But overall flood risk management is a permissive duty not an obligation. If we withdraw protection no compensation is required, but if we flood land we must compensate. And, if we decide to stop pumping water out, we are liable. A national newspaper recently picked up that we were spending thousands of pounds pumping water from a (coastal marshland) area to stop it flooding, although it is now covered by drought orders. We are currently paying £20 million, principally to protect the habitat of breeding pairs of birds in a part of East Anglia. But under coastal erosion provisions, there is no mechanism whereby owners of homes that are falling into the sea elsewhere in East Anglia can be compensated. Government is under pressure to defend all areas of the coast with hard defences, but this is not a tenable strategy in the long term. Some difficult decisions have to be made.

Research Needs

Most water and flood risk planning horizons end before the 2050s, the point at which climate-driven changes in regional rainfall (and some river flows) are expected to emerge from natural variability. Figure 5 shows that for the UK, temperature will be a much stronger climate change signal for some time and that we are unlikely, in most cases, to detect climate-driven trends in river flows for several decades to come (Wilby, 2006).



European summer temperature anomalies under medium-high emissions. Source: Hadley Centre

Summer precipitation anomalies downscaled for the Thames Basin. Source: Diaz-Nieto and Wilby (2005)

Figure 5. Natural climate variability remains important in the 2020s.

This implies the need for:

- Comprehensive appraisal of water sector risks in all sectors and biomes related to rising air, river, ground, estuarine, and coastal water temperatures.
- Robust statistical techniques for separating climate change signals in "noisy" environmental data sets from natural variability.
- Frameworks for capturing key sources of uncertainty affecting regional climate change scenarios and impacts in the 2020s.
- Integrated tools for demonstrating economic and environmental benefits of adaptation at river basin scales over the next few decades and beyond.
- Data mining and modelling campaigns to test that existing water supply and flood defence infrastructure can cope with the full range of natural variability (especially known historic extremes), as the first step in climate-proofing.
- Better data collection on impacts and responses to current extreme weather events (which are expected to become the normal experience later in the century).

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Session 5:

Climate change and the water dimension in the MS: research and policy

Case study 3: Netherlands policies and initiatives on adaptation to climate change Water management is climate adaptation

Joost Buntsma,

Ministry of Transport, Public Works and Water Management, Then Netherlands

Introduction

Scientists are still debating exactly how things are likely to progress, but one thing is clear: the climate is set to change dramatically under the influence of human activity. As the Dutch Meteorological Office KNMI is already telling us, it is going to rain more often and more heavily in the future. More severe storms are already expected to become a feature of our weather this century. We might perhaps see a few less Elfstedentocht ice-skating marathons, but we can certainly expect more long, hot, dry summers like that of 2003. And also this year a long hot July was followed by an extremely wet month of August.

Threatening floods along the Rhine 1995

We have already had a taste of these extremes of wet and dry conditions. In the 1990s (and recently also in the Westland region) we had several episodes of major flooding that caused billions of euros' worth of damage. In 1995 as many as 200,000 people had to be evacuated along the major rivers when dikes threatened to break. In summer 2003 the hot summer weather lasted so long that the land began to dry out, and the temperature of surface waters rose considerably. There was no longer any possibility of natural cooling, as the ground was too dry, a shortage of cooling water for power stations threatened to cause an energy crisis, and smaller and smaller vessels had to be used to transport cargo to and from Germany as water levels in the Rhine fell to an all-time low. This was the threat we faced from above.

Groninger Museum in 1998

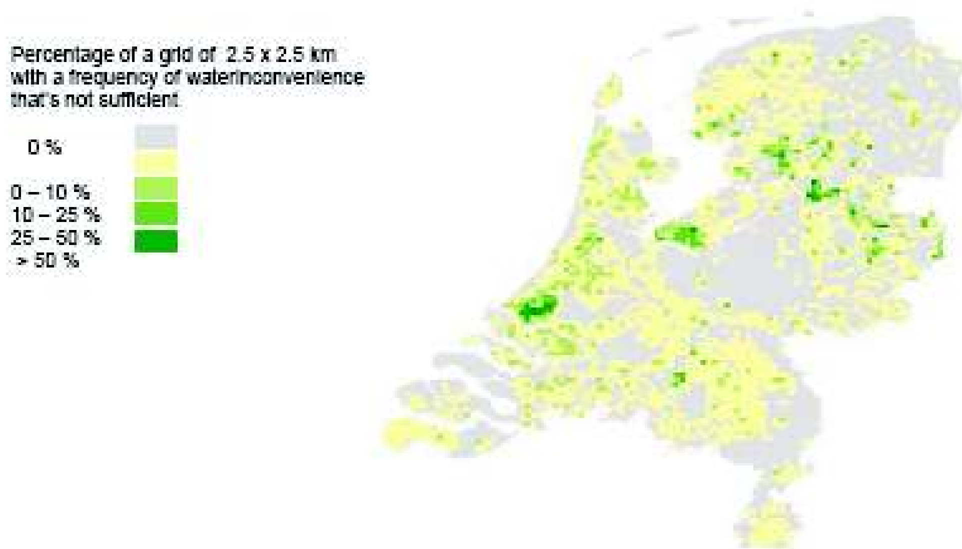
Low discharge Rhine 2003

National Administrative Agreement on Water

In The autumn of 2000 parts of Holland had to deal with heavy rainfall. Water was on the streets and in the houses. Water managers and politicians felt a sense of urgency. The National Administrative Agreement on Water is being put into practice and that means a new water management policy in the 21st century. The Spatial Policy Document is having a major impact on its implementation and addresses the water issues. A key planning decision entitled 'Room for the Rivers', the Maaswerken project, the Integrated Water Act and a new policy on coastal areas are all examples of how we are handling water differently.

The national task for provincial and local authorities and property developers is: retain water in the area where it falls as rain, store it if it is no longer possible to retain it and, as the final option, drain it away. Water impact assessment of spatial plans will ensure that authorities' plans include details of how they intend to deal with the water issue, and how they will ensure the problem does not simply get passed on. If developments are knowingly built in unsuitable locations, those who took the decisions will be held responsible.

This agreement prescribed (concepts for) standards for the allowed frequency for water inconvenience (not safety). With the climate scenario's as input the Dutch water boards calculated the frequency of flooding due to rainfall according the climate scenario's. The map shows the results of the confrontation between the modelling results and the concept standards. From the green grids more than 50% of the area suffers a frequency that's to high and measurements are necessary. At this moment tere are already more than 300 running projects. For the whole operation the water boards need an amount of 2,5 billion euros until 2015.



Scorecard NBW standards 2005

Room for the river

In the middle ages we started to build dikes to protect larger areas and thus created our polders. Over the years we perfected the art of dike or in your terms levee construction. Now at the beginning of the 21st century more than half of the Netherlands should flood without dikes.

After more than two generations without serious threats, flooding occurred in 1993 and 1995. This time we survived without serious damage or losses of life, but only just. We realized that this could not go on forever. Our government changed tack and developed a long-term view that allows more room for the river. The policy and the project were labelled: 'Room for the River'

AGENDA

INTERNATIONAL WORKSHOP

CLIMATE CHANGE IMPACTS ON THE WATER CYCLE, RESOURCES AND QUALITY- Research-Policy interface

Brussels, 25-26 September 2006

Co-organised by: Directorate-General for Research (*Environment-Climate Unit*), **Directorate-General for Environment** (*Protection of Water and Marine Environment Unit)* and **Directorate-General Joint Research Centre** (*Institute for Environment and Sustainability*) **European Commission**

Programme

Day 1

8:30	Registration
9:00	**Opening** by Roland Schenkel, Director-General of the Directorate-General Joint Research Centre (on behalf of the three Directorates-General)
9:10-9:30	**Overview of climate change projections in Europe** Daniela Jacob, Max-Planck Institute, Germany
9:30-9:50	**Climate change research in the 7th Framework Programme** Elisabeth Lipiatou, Directorate-General for Research, Environment-Climate Unit
9:50-10:10	**Climate change and EU water policy** Peter Gammeltoft, Directorate-General for Environment, Protection of Water and Marine Environment Unit
10:10-10:30	**Climate change research at the Joint Research Centre** Frank Raes, Directorate-General Joint Research Centre, Institute for Environment and Sustainability, Climate Change Unit
10:30-10:45	*Coffee break*

10:45-13:00	**Session 1:** **Climate change impacts on water cycle and water resources - floods and water scarcity** Chair: Pavel Kabat, Wageningen University, the Netherlands Rapporteur: Marta Moren/Philippe Quevauviller
10:45-11:10	**A risk analysis for world freshwater availability under future climate change** Marko Scholze, University of Bristol, United Kingdom
11:10-11:35	**Climate change and floods in Europe** Luc Feyen, Directorate-General Joint Research Centre, Institute for Environment and Sustainability, Land Management and Natural Hazards Unit
11:35-12:00	**Climate change and drought: the role of critical thresholds and feedbacks** Millán Millán, Fundación CEAM, Spain
12:00-12:25	**Climate change impacts on water resources in developing countries** Jan Polcher, Centre National de la Recherche Scientifique, France
12:25-13:00	**Climate change impacts on global water cycle and projections for Europe** Pavel Kabat, Wageningen University, the Netherlands
13:00-14:00	*Lunch*
14:00-17:45	**Session 2:** **Climate change impacts on water quality – nutrients, organic content, toxic compounds, ecological status and biodiversity** Chair: Rick Battarbee, University College of London, United Kingdom Rapporteur: Peeter Noges/Anne Lyche Solheim
14:00-14:25	**Sensitivity of freshwater ecosystems for climate change impacts** Thorsten Blenckner, Uppsala University, Sweden
14:25-14:50	**Status and requirements for climate change research in European regional seas** Nicolas Hoepffner, Mark Dowell and Wolfram Schrimpf, DG JRC, Institute for Environment and Sustainability, Global Environment Monitoring Unit
14:50-15:15	**Impacts of climate change on cycling, accumulation and feedbacks of chemicals in aquatic ecosystems** Jordi Dachs, Consejo Superior de Investigaciones Científicas, Spain
15:15-15:30	*Coffee break*
15:30-15:55	**Climate change impacts on aquatic ecosystems: critical thresholds for water policies** Carlos Duarte, Consejo Superior de Investigaciones Científicas, Spain
15:55-16:25	**Climate change & projections on water quality changes in Europe - Aquatic ecosystem response to climate change: past, present and future"** Rick Battarbee, University College of London, United Kingdom
16:25-17:45	Round table/discussion (Sessions' chairs + EC representatives + Experts)
17:45	*End of first day*

Day 2

9:00-11:30	**Session 3:** **Economic and social implications associated with changes in the water cycle and resources induced by climate change** Chair: Daniela Jacob, Max-Planck Institute, Germany Rapporteur: Luc Feyen/Anna-Stiina Heiskanen
9:00-9:25	**Impacts of climate change in Europe: the PESETA project** Juan Carlos Ciscar Martinez, Directorate-General Joint Research Centre, Institute for Prospective Technological Studies
9:25-9:50	**Water resources and climate change: impacts on agriculture in Europe** Jørgen E. Olesen, Danish Institute of Agricultural Sciences, Denmark
9:50-10:15	**Long-term planning of flood risk management** Jochen Schanze, Dresden Flood Research Centre, Germany
10:15-10:40	**Land use and climate change** Michael Obersteiner, International Institute for Applied System Analysis, Austria
10:40-11:05	**Impacts on water resources and hydropower production** Nils Roar Sælthun, University of Oslo, Norway
11:05-11:30	**Climate change and human dimension: Health impacts of floods** Debarati Guha-Sapir, Université. Catholique de Louvain, Belgium
11:30-11:45	*Coffee break*
11:45-13:00	**Session 4:** **Adaptation needs of water resources management in Europe** Chair: Z. W. Kundzewicz Rapporteur: Philippe Quevauviller/Marta Moren
11:45-12:05	**Green paper on climate change and adaptation measures** Abigail Howells, Directorate-General for Environment
12:05-12:25	**Adaptive water management as a response to cope with implications of climate change** Jörn Möltgen, University Of Osnabrück, Germany
12:25-13:00	**Climate change impacts on water management and adaptation needs in Europe** Zbigniew W. Kundzewicz, Research Centre for Agricultural and Forest Environment, Polish Academy of Sciences, Pozna, Poland
13:00-14:00	*Lunch*

14:00-17:30 **Session 5:**
Climate change and the water dimension in the MS: research and policy
Chair: Fritz Holzwarth, Water Director, Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, Germany
Rapporteur: Philippe Quevauviller

14:00-14:25 **Introduction to national adaptation strategies for climate impacts on water resources in the EU**
André Jol, European Environment Agency, Denmark

14:25-14:50 **Case study 1: the Spanish strategy: national adaptation plan to climate change**
José Ramón Picatoste Ruggeroni, head of the impacts and adaptation unit in the Spanish Climate Change Office, Ministry for Environment, Spain

14:50-15:15 **Case study 2: UK adaptation strategy in the water sector: approach and issues**
Merylyn McKenzie Hedger or Rob Wilby, Environment Agency, United Kingdom

15:15-15:40 **Case study 3: Strategy in the Netherlands**
Joost Buntsma, Ministry of Transport, Public Works and Water Management, General Directorate for Water, the Netherlands

15:40-16:00 *Coffee break*

16:00-17:30 **Final plenary:**
Report and discussions by the sessions' chairs
Conclusions and way forward by:
José Manuel Silva Rodríguez, Director-General, Directorate-General for Research (on behalf of the three Directorates-General)

17:45 *End of the workshop*

LIST OF PARTICIPANTS

Workshop on Climate Change impacts on the water cycle, resources and quality

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25/09/2006 - 26/09/2006

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European Commission

EUR 22422 — International Workshop on Climate Change Impacts on the Water Cycle, Resources and Quality

Luxembourg: Office for Official Publications of the European Communities

2007 — 149 pp. — 17.6 x 25.0 cm

ISBN 92-79-03314-X