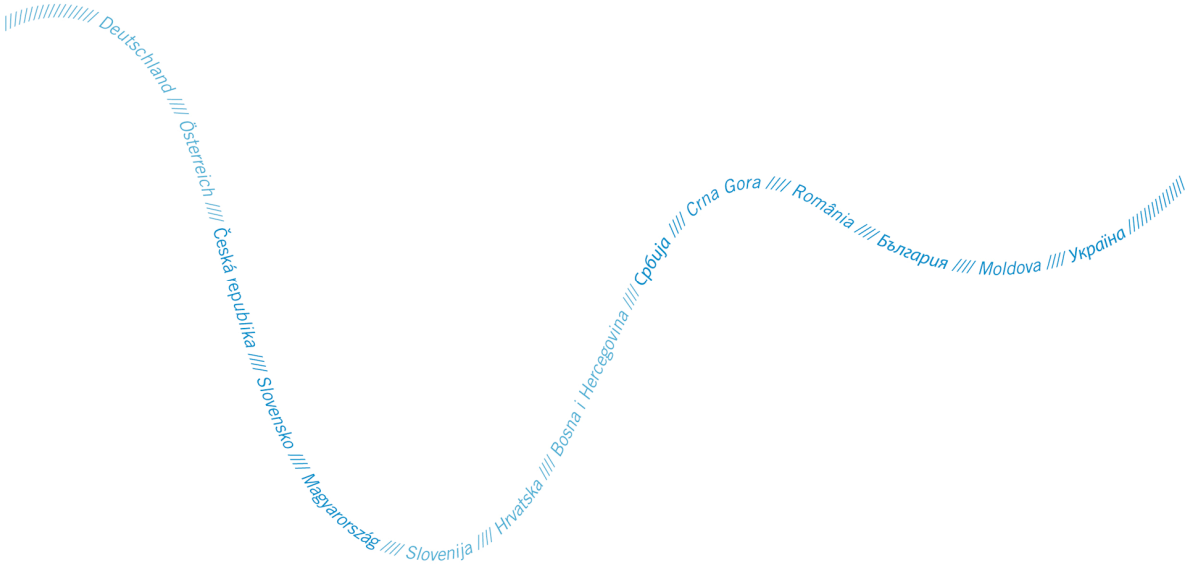
Summary of eventual main impacts on water resources due to climate change and list of selected climate change projects relevant to the DRBD

icpdr International Commission for the Protection of the Danube River
iksd Internationale Kommission zum Schutz der Donau

Annex 21 of the DRBM Plan



1. Eventual main impacts of climate change on water resources in the DRB

There have been a number of recent and ongoing international research initiatives on climate change that are of relevance to the Danube River Basin (DRB). They are useful in identifying some of the issues that may impact the environment of the DRB. A summary of the key relevant projects is given in section 2 below.

Based on the findings of these initiatives, a set of impacts from climate change can be anticipated within the DRB. Direct climate change impacts that may have adverse effects on the wider environment can be identified (e.g. changes in precipitation; changes in ecoregions) but also impacts can be identified that specifically affect aquatic ecosystems and their populations. Further, indirect climate change impacts may be expected as a result of climate effects on the industrial and agricultural sectors, which may in consequence impact on the environment. For both groups, the key impacts on the aquatic environment are summarised below:

Direct climate change impacts can provoke hydrological alterations within the waters of the DRB through extreme events such as drought and floods. Respective pressures can negatively affect the *ecological* and *chemical status* of the water:

- In the case of **drought events**, hydrological alterations such as significant decreases in water flows; disconnection of active wetland/floodplain areas; changes in sediment transport; increases in local pollution concentrations and insufficient groundwater recharge may impact water status.
- In the case of **flood events**, hydrological alterations can result in, for example, an increased mobilisation of pollutants and increased land erosion impacting on aquatic populations. In addition, occurrence of flood events at different frequencies can adversely impact water status.

Direct climate change impacts can also have adverse effects on basic physical and chemical conditions relevant for the aquatic environment (e.g. water temperature, pollution concentrations, etc.) and thus affect water status. Further, issues such as **salt water intrusion** in coastal areas due to sea level rise and/or the reduction of river levels are also potentially significant pressures.

Indirect climate change impacts result in additional threats to the DRB environment:

- **Drought events** may provoke an increase in water demand from various sectors including agriculture, water supply, navigation, hydropower and thermal energy generation. The additional need for water abstraction from listed water users could potentially increase the already existing pressure on the aquatic environment and thereby further decrease water status.
- Increased **flood events** can result in the need for additional flood defence measures that, if they don't take into account the needs of the aquatic environment as part of the planning process, can provoke negative impacts on water status. Wherever possible and without putting humans and settlement at risk, alternative flood defence solutions (such as flood retention areas) that are also beneficial to the aquatic environment, should be considered.

In summary, respective actions need to be taken to ensure that additional water use and flood defence measures will be *climate proof* in the future. *Climate proof* measures will ensure that additional impacts on the aquatic environment and water status are prevented and the achievement of environmental objectives ensured.

2. List of climate change projects relevant to the DRBD

1. ADAM:[2] Adaptation and Mitigation Strategies - supporting European climate policy.

Funded by the European Commission and co-ordinated by the Tyndall Centre for Climate Change Research in the UK, ADAM is an integrated research project running from 2006 to 2009 that will lead to a better understanding of the trade-offs and conflicts that exist between adaptation and mitigation policies. ADAM will support EU policy development in the next stage of the development of the Kyoto Protocol and will inform the emergence of new adaptation strategies for Europe.

Evidence so far from the Tisza region suggests that successful adaptation requires both formal regulatory rules and informal social relations.

The Tisza River Basin: Adaptation to climate change in floodplain management

Water management in the Hungarian Tisza region offers an attractive case to study mainstreaming adaptation and mitigation. Climate change is connected to the three main water-related problems of the Tisza region: floods, in-land water stagnation and droughts. The new water management plan calls for rural development, water retention and the revitalisation of floodplains. Implementation of the plan is hard, however, since the benefits remain unquantified and property rights are ill-defined. Opportunities are thereby missed to capitalize on the potential of ecosystems to regulate floods and droughts.

In the spring of 2003, the Hungarian government issued a decree that marked a substantial shift in addressing water management. The new water management plan for the Tisza River in Eastern Hungary recognised rural development and nature conservation as important objectives next to flood protection. Floodplain revitalisation and land-use change were introduced as strategies to replace or complement prevailing engineering approaches. This was surprising because for 150 years water management had been dominated by river regulation, the construction of embankments and drainage. Water management had served mostly the interests of large-scale agriculture.

The ADAM project is studying what happened in Hungary in the period leading up to the breakthrough year of 2003 and in the following years when actors had to deliver on the new direction taken in water management. It is examining under what conditions floodplain revitalisation, land-use change and rural development reduce climate-related risks in the Hungarian Tisza River Basin. The multidisciplinary team assesses the agricultural and hydrological consequences of climate change, as well as the institutional setting conducive to climate change adaptation and mitigation.

Evidence from the Tisza region so far suggests that successful adaptation requires both formal regulatory rules and informal social relations. Informal relations are crucial in strengthening autonomous adaptation and to capitalise on local traditions and experience. At the same time, formal rules can mainstream adaptation into policy cycles and are required to include adaptation in longer term planning, investment and large-scale infrastructure. Yet, the regulatory framework and operational implementation are hardly addressed in regional adaptation policy-making. Government organisations are under-prepared to mainstream and to finance integrated adaptation policies where the cooperation among ministries is crucial. The importance of informal relations is often overlooked in policy-making. This includes creating 'space for learning and feedback' pilots and facilitating new ways of working between academics, stakeholders, experts and policy-makers. Allowing actors to clarify and change their roles and responsibilities in both policy development and implementation can support adaptation and deserves more attention. The sharing of costs and benefits between actors is central to the successful implementation of adaptation and has to be addressed in vulnerability studies and adaptation planning.

[2] ADAM - www.adamproject.eu/

2. CECILIA[3]: Central and Eastern Europe Climate Change Impact and vulnerability Assessment.

The main objective of CECILIA is to deliver a climate change impact and vulnerability assessment in targeted areas of Central and Eastern Europe. Emphasis is given to applications of regional climate modelling studies at a resolution of 10 km for local impact studies in key sectors of the region. The project contains studies of hydrology, water quality and water management (focusing at medium-sized river catchments and the Black Sea coast); air quality issues in urban areas (Black Triangle - a polluted region around the common borders of the Czech Republic, Poland and Germany); agriculture (crop yield, pests and diseases, carbon cycle); and forestry (management, carbon cycle). Very high resolution simulations over this region are necessary due to the presence of complex topographical and land-use features. Climate change impacts on large urban and industrial areas modulated by topographical and land-use effects (which can be resolved at the 10 km scale), are investigated by CECILIA. The high spatial and temporal resolution of dense national observational networks at high temporal resolution and of the CECILIA regional model experiments will uniquely feed into investigations of climate change consequences for weather extremes in the region under study. Comparison with the results based on statistical downscaling techniques will also be provided. Statistical downscaling methods for verification of the regional model results will be developed and applied, and assessments of their use in localization of model output for impact studies will be performed.

3. CIRCLE[4]: Climate Impact Research Co-ordination for a Larger Europe

Different regions face different problems: in low-lying coastal areas, researchers are looking at the effects of rising sea levels, while in high mountain areas, melting glaciers that increase the risk of mass movements will attract attention. Some institutes are carrying out numerical modelling of climate patterns, while others are looking at the social and economic impact of change. Coordinated information about these national research programmes will enable partners to learn from each other, and avoid duplication.

CIRCLE is organised into four activities to integrate what is already being done at the national level and to take it forward as a unified effort.

The first activity involves *learning from each other*: CIRCLE requires an interdisciplinary approach to integrate indicators of climate change. As well as climatology, meteorology, hydrology, biology, soil sciences, marine sciences and forestry, building technologies, sociology and medicine come into play in respect to impacts on human health, for example, impacts due to heat waves and the possible spread of vector-borne infectious diseases.

Learning will involve *exchange of knowledge and experience* gained on national programmes, their scientific focus and management practices.

This leads to *planning*: defining tangible ways for the national programmes to support each other on specific issues. It should then be possible to set up working links by connecting national programmes for their mutual benefit.

The fourth and major strand is to fulfil the criteria for an *ERA-NET* (European Commission scheme aimed at integrating and enhancing European research) by establishing trans-national research programmes and joint calls for proposals that aim at a stepwise alignment of national research agendas.

[3] CECILIA - www.cecilia-eu.org/

[4] CIRCLE - www.circle-era.net/

4. CLAVIER[5] – Climate Change and Variability: Impact on Central and Eastern Europe

The nations in Central and Eastern Europe (CEE) face the triple challenge of ongoing economic and political transition; continuing vulnerability to environmental hazards; and the longer term impacts of global climate change. The overall aim of the EU Sixth Framework Programme (6thFP) project, CLAVIER, is to make a positive contribution to successfully coping with these challenges. Three representative CEE Countries are studied in detail: Hungary, Romania, and Bulgaria.

In the framework of CLAVIER, ongoing and future climate changes are analysed based on existing data and very detailed climate projections in order to fulfil the needs of local and regional impact assessment. Researchers from 6 countries and various disciplines are investigating linkages between climate change and its impact on weather patterns, air pollution, extreme events and water resources. Furthermore, an evaluation of the economic impact on agriculture, tourism, energy supply and the public sector is being conducted.

5. ENSEMBLES[6]: Providing ensemble-based predictions of climate and their impacts

This project involves computation of climate change signals using Regional Climate Models driven by various Global Models assuming one IPCC (Intergovernmental Panel on Climate Change) emission scenario (A1B). The project aims to:

- Develop an ensemble prediction system for climate change based on the principal state-of-the-art, high resolution, global and regional *Earth System* models developed in Europe, validated against quality controlled, high resolution gridded datasets for Europe. This will produce for the first time, an objective, probabilistic estimate of uncertainty in future climate at the seasonal to decadal and longer timescales.
- Quantify and reduce the uncertainty in the representation of physical, chemical, biological and human-related feedbacks in the *Earth System* (including water resource, land-use and air quality issues, and carbon cycle feedbacks).
- Maximise the exploitation of the results by linking the outputs of the ensemble prediction system to a range of applications, including agriculture, health, food security, energy, water resources, insurance and weather risk management.

6. GLOCHAMORE[7]: Global Change in Mountain Regions

GLOCHAMORE was a support action of the EU's 6thFP on "Sustainable Development, Global Change and Ecosystems". The project aimed at the development of a state-of-the art integrated and implementable research strategy to gain a better understanding of the causes and consequences of global change in a selection of 28 UNESCO Mountain Biosphere Reserves (MBRs) around the world.

The results of this research strategy serve as a basis for MBR managers and other stakeholders to develop sustainable development policies for their respective MBRs. In order to meet its objectives, the project has integrated activities and knowledge from both (natural and social) science and from UNESCO Mountain Biosphere Reserve managers.

7. MICE[8]: Modelling the Impact of Climate Extremes

MICE uses information taken directly from climate models to explore future changes in extreme events across Europe in response to global warming.

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[5] CLAVIER – http://www.clavier-eu.org

[6] ENSEMBLES - http://ensembles-eu.metoffice.com/

[7] GLOCHAMORE - http://mri.scnatweb.ch/projects/glochamore/

[8] MICE - http://www.cru.uea.ac.uk/projects/mps/html/mice.html

The objectives are:

- To identify and catalogue extremes in observed and modelled climate data;
- To evaluate the extent to which state-of-the-art climate models can successfully reproduce the present-day occurrence of extremes;
- To analyse future changes in climate extremes using a range of statistical techniques including Extreme Value Theory;
- To assess the impact of these changes in extremes on selected activity sectors;
- To communicate the results to stakeholders.

By looking at results from a number of climate model experiments, MICE will explore the uncertainties associated with predicting the future occurrence of extremes. These experiments will be selected to look at the effects of changing the model resolution (comparing regional and global climate model experiments); of using different scenarios of atmospheric greenhouse gas concentrations (which in turn reflect different visualizations of economic futures); and of using different model ensemble members (analysing relationships between natural variability and forced change).

The impact sectors to be investigated range from those where the relationships between climate and impact are well understood (agriculture, energy use) and those where the potential implications of climate change are multi-faceted/complex and only just beginning to be appreciated (forestry, winter sports and beach holidays).

8. PRUDENCE[9]: Prediction of Regional scenarios and Uncertainties for Defining European Climate risks and effects

This project involves computation of climate change signals using Regional Climate Models (>10) all driven by one Global Model (HadAM3H GCM) under one IPCC emission scenario (A2).

PRUDENCE is a European-scale investigation with the following objectives:

- To address and reduce deficiencies in projections;
- To quantify our confidence and the uncertainties in predictions of future climate and its impacts, using an array of climate models and impact models and expert judgement on their performance;
- To interpret these results in relation to European policies for adapting to or mitigating climate change.

Climate change is expected to affect the frequency and magnitude of extreme weather events, due to higher temperatures, an intensified hydrological cycle or more vigorous atmospheric motions. A major limitation in previous studies of extremes has been the lack of: appropriate computational resolution (obscures or precludes analysis of the events); long-term climate model integrations (drastically reduces their statistical significance); and co-ordination between modelling groups (limits the ability to compare different studies). These three issues are all thoroughly addressed in PRUDENCE by using state-of-the-art, high resolution climate models; by co-ordinating the project goals to address critical aspects of uncertainty; and by applying impact models and impact assessment methodologies to provide the link between the provision of climate information and its likely application to serve the needs of European society and economy.

PRUDENCE will provide a series of high-resolution climate change scenarios for 2071-2100 for Europe, characterising the variability and level of confidence in these scenarios as a function of uncertainties in model formulation, natural/internal climate variability, and alternative scenarios of future atmospheric composition. The project will provide a quantitative assessment of the risks arising from changes in regional weather and climate in different parts of Europe by estimating future changes in extreme events such as flooding and windstorms and by providing a robust estimation of the likelihood and magnitude of such changes. The project will also examine the uncertainties in potential impacts induced by the range of climate scenarios developed from the climate modelling results. This will provide useful information for climate modellers on the levels of accuracy in climate scenarios required by impact analysts. Furthermore, a better appreciation of the uncertainty range in calculations of future impacts from climate change may offer new insights into the scope for adaptation and

[9] PRUDENCE - http://prudence.dmi.dk/

mitigation responses to climate change. In order to facilitate this exchange of new information, the PRUDENCE work plan places emphasis on the wide dissemination of results and preparation of a non-technical project summary aimed at policy makers and other interested parties.

9. STARDEX[10]: Statistical and Regional dynamical Downscaling of Extremes for European regions

The climate of the 21st century is likely to be significantly different from that of the 20th because of anthropogenically-induced climate change. The Kyoto Protocol and future initiatives, together with actions taken by the EU, are expected to reduce the impacts of the changes, but significant changes will still occur. These changes will be perceived by European citizens mostly through increases in some types of extreme weather. STARDEX aims to provide scenarios of expected changes in the frequency and intensity of extreme events (such as heavy precipitation and resultant flooding and high temperatures) which are likely to have an impact on human lives and activities and on the environment. Climate change scenarios, particularly those for extremes, are needed for all aspects of future design (e.g. water resources, agriculture, irrigation, storm and land drainage, road, railway and building design and other sectors such as tourism) where the weather and climate are key determinants of everyday life. In all these aspects there is a clear European-wide need for more reliable, high-resolution scenarios of extremes. STARDEX will not be making predictions, but providing information on the likely changes in extremes. If work of this kind is not undertaken, future designs will not be able to incorporate the latest information about changes in extreme climate in the future.

STARDEX will achieve its aims by a rigorous and systematic inter-comparison of the three main downscaling methods (statistical, dynamical and statistical-dynamical) that are used to construct scenarios of extremes at the time and space scales where they are most needed. STARDEX will identify the more robust downscaling techniques and apply them to provide reliable and plausible future scenarios of temperature and precipitation-based extremes for selected European regions for the 2071-2100 timeframe. The extreme scenarios will incorporate three forms of uncertainty related to the specific downscaling method, different future emission paths and inter- and intra-model variability. To achieve these aims, STARDEX will develop standard observed and climate model data sets and a diagnostic software tool for calculating a standard set of extreme statistics across Europe. Two of the major climate models in Europe (HadCM3 and ECHAM4/OPYC) will be extensively validated, with the particular emphasis on extremes. The inter-comparison of downscaling methods will take place using observed climate data from the second half of the 20th century. Finally, recent extremes across Europe will be analysed. What were their causes and impacts? Was anthropogenic climate change a factor? What can be learned from the recent past? The analysis of the recent past will bring together representatives from the re-insurance industry and the climate modelling and climate impact communities in an expert advisory panel.

The impacts of STARDEX will be improved methodologies for the development of scenarios of extremes, with recommendations as to which are best for different regions across Europe and for different variables. The various sectors listed above will be able to find off-the-shelf scenarios of extremes relevant to their business, incorporating all the various uncertainties. The scenarios will be used for many aspects of design (e.g. modification of dam design criteria, agricultural potential and alteration to insurance premiums) where extremes of weather are crucial determinants. The results will be made available through standard methods of scientific publications and reports, conferences and the World-wide Web.

9. GLOWA[11]. Danube project (Impact of Global Change on the Upper Danube

GLOWA-Danube is a research and development program focusing on the comprehensive analysis of the future of water resources of the Upper Danube. In GLOWA-Danube the impact of Climate Change of a broad range of sectors is investigated. Furthermore the project identifies and simulates strategies

[10] STARDEX - www.cru.uea.ac.uk/projects/stardex/

[11] GLOWA - www.glowa-danube.de

for adaptation to and mitigation of the consequences of Climate Change and tests their effectiveness. In GLOWA-Danube a team of researchers from different natural and socio-economic science disciplines work closely together in an interdisciplinary, university-based competence network since 2001.

The aim of GLOWA-Danube is to investigate with different scenarios the impact of change in climate, population and land use on the water resources of the Upper Danube and to develop and evaluate regional adaptation strategies. For this purpose the decision support system DANUBIA was successfully set up within the first and second project stage (2001-2006).

DANUBIA is a coupled simulation model. It includes for the first time model components for natural science as well as socio-economic processes and their interactions. With the intension of being predictive DANUBIA uses results of regional climate models for predictions on Climate Change. Physical and physiological components describe natural processes (hydrology, hydro-geology, plant physiology, yield, and glaciology). For the simulation in the included sectors (farming, economy, water supply companies, private households and tourism) DANUBIA uses deep multi-actors models which represent the decisions of the involved actors based on the structure of societies, their framework as well as their interests. All components of DANUBIA run parallel on an inexpensive LINUX-cluster. DANUBIA was carefully and successfully validated with comprehensive data sets of the years 1970-2005 and is now available in the third stage of the project for common use for project researchers and stakeholder. DANUBIA will be made available as "Open Source" at the end of the third project stage in2010 and will particularly serve decision makers from policy, economy, and administration as tool for a foresighted planning of water resources against the background of Global Change. DANUBIA is applied to the watershed of the Upper Danube.