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KLIWAS

Impacts of Climate Change on Waterways and Navigation in Germany

First Status Conference
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Public Information Service
Invalidenstraße 44
10115 Berlin
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Download at: www.bmvbs.de

Editorial team
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Andrea Mehling, Federal Institute of Hydrology, Koblenz
Michael Schleuter, Federal Institute of Hydrology, Koblenz
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Federal Institute of Hydrology, Koblenz

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The advance of climate change on a global scale will bring about changes in our living conditions – and Germany is no exception. Experts expect far-reaching consequences for the environment, economy and society, if we do not at least succeed in limiting global climate change. Even if the ambitious EU target is achieved, that is, the restriction of the increase in the average global temperature to less than 2°C above the pre-industrial level, consequences of climate change will occur nonetheless, and we will be forced to adapt our lifestyle accordingly.

A responsible climate policy must take all possible action to effectively reduce the emission of green-house gases. Germany plays a leading role in this international scenario. The Federal Ministry of Transport, Building and Urban Development (BMVBS) is supporting this role with ambitious measures for climate protection, in particular in the fields of transport and housing construction. Furthermore, we must now begin to develop adaptation strategies for the unpreventable effects of climate change.

Even in times of economic crisis, the preparations for adaptation to climate change may not be pushed off the political agenda. Climate change will affect all areas of life and activity and continue to preoccupy us long after the economic crisis. Timely and well-founded preparations will enable us to base our planning on the latest information about the possible impact of climate change at an early stage, thus setting us on the right course for the future.

On the basis of a report published in February 2008 by the Federal Ministry of Transport, Building and Urban Development (BMVBS), a five-year research programme was launched in 2009 with the title KLIWAS, "Impact of Climate Change on Waterways and Navigation – Options to Adapt". The purpose of KLIWAS is the identification of the impact of climate change and the development of options for adaptation in the fields of waterways and navigation in Germany.

Through the KLIWAS research programme the BMVBS will make a significant contribution on behalf of the environment and climate-friendly method of transport "ship/waterway" in the context of the European and national climate change adaptation strategy. In the year 2007, the BMBVS already combined its departmental research institutes, the National Meteorological Service of Germany (Deutscher Wetterdienst, DWD), the German Maritime and Hydrographic Agency (Bundesamt für Seeschifffahrt und Hydrographie, BSH), the German Federal Institute of Hydrology (Bundesanstalt für Gewässerkunde, BfG) and the German Federal Waterways Engineering and Research Institute (Bundesanstalt für Wasserbau, BAW) into an alliance which works closely with the national and international network for climate research and climate impact research and which directs and implements this programme under the auspices of the Federal Institute of Hydrology. An international consultative committee constituted on 2nd March 2009, will advise and support the programme with its specialist knowledge. It is gratifying that other departments (BMU: Federal Ministry for the Environment, Nature Conservation and Nuclear Safety; BMBF: Federal Ministry of Education and Research; and BMELV Federal Ministry of Food, Agriculture and Consumer Protection) also support this programme and recognise the synergy for other sectors which will also be impacted by the alterations in the water balance in coastal and inland waterways in Germany (for instance, water management, coastal protection, environmental protection, nature protection and agriculture).

The climate projections that have been available hitherto regarding the development of precipitation and water balance in river catchment areas and coastal waters still cover a very wide spectrum and show, at least in part, contradictory trends. KLIWAS should provide a reliable basis for the development of suitable options and strategies for adaptation. This means that bad investments with far-reaching consequences can be avoided.

The research programme KLIWAS was officially launched at the First Status Conference which took place in Bonn at the BMBVS on 18th and 19th March 2009. I would like to thank all those participants who have spent several years investing their expertise in the preparation of this programme. The large and heterogeneous group of participants at the First Status Conference is evidence of the extent of the interest in the KLIWAS research programme shown by the professional public. This First Status Conference and the conference volume provide an overview of the research contents of KLIWAS, the importance of KLIWAS for the adaptation strategy in Germany and of the first results for the Rhine waterway.

I will be eagerly awaiting the results as they gradually become available and the related, new scientific knowledge. I am convinced that with this research alliance we will be well equipped to face the challenges of adaptation to climate change in a responsible way.

Enak Ferlemann
Parliamentary State Secretary
Federal Ministry of Transport, Building and Urban Development

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A1 Introduction and Foundations

Introduction to the KLIWAS Programme

Bernd Törkel, Director of the Waterways and Shipping Directorate-General at the Federal Ministry of Transport, Building and Urban Development (BMBVS)

Climate change is not a new phenomenon. As documented in the fourth and most recent report of the Intergovernmental Panel on Climate Change (IPCC, 2007), the rate of global warming has shown unusual acceleration in recent decades and it has been proven indisputably that this development is, at least in part, of anthropogenic origin. This knowledge challenges us to take action, and the political world is reacting with a variety of initiatives and measures. On the one hand, measures for reducing emissions are intended to prevent an excessive rate of warming and its negative consequences (climate protection) and, on the other, we must adjust to the unavoidable consequences as early as possible (climate adaptation).

The European Council of the heads of state and governments of the EU member states set the course for an integrated European climate and energy policy under the Germany presidency in the spring of 2007. This includes ambitious goals for climate projection (restriction of warming in Europe to 2°C) along with goals for the expansion of renewable energy sources and an increase in energy efficiency. With its decision at Meseburg in August 2007, for an Integrated Energy and Climate Programme, the German Federal Government is implementing the European directive decisions on a national level by means of a specific programme of action. The implementation of the Energy and Climate Programme will be aimed at achieving the climate objectives in an ongoing process until the year 2020. With the High-Tech Strategy for Climate Protection (BMBF, 2007) the Federal Government is concentrating research and innovative resources in the economic and scientific sectors in Germany more strongly on these objectives.

Although navigation is already an extremely climate-friendly mode of transport, the Federal Ministry of Transport, Building and Urban Development (BMVBS) is working on several initiatives aimed at still further reducing CO_2 emissions from navigation in coastal and inland areas. A current and successful example is the resolution of the IMO of October 2008 by which, as a result of the initiative of the BMVBS, pollutant emissions from navigation will in future be reduced through the compulsory use of environmentally sound fuels. Further fuel-saving measures are being actively pursued in close cooperation with the international community of states. For inland navigation, the Waterways and Shipping Directorate-General of the BMVBS is paving the way with, for example, the proposal for further development of maximum limits for exhaust gases within the scope of the CCNR and EU; the research project on the use of particle filters; the study on the compatibility of sulphur-free fuels for the engines of inland vessels and with the subsidised programme for the exchange of ships' engines.

Parallel to this, processes for the preparation of strategies for adaptation have begun on a European as well as a national level. In 2007 the European Commission adopted a Green Paper and, in 2009, a White Paper on adaptation to climate change. On this basis, the European Commission obliges the member states to identify the regional impact of climate change, discern gaps in knowledge and develop technical solutions for adaptation measures. On 17th December 2008, the German Federal Government passed the German Strategy for Adaptation to Climate Change (DAS) which sets out a framework for the gradual development of adaptation strategies in Germany. This strategy lays the foundation stone for a mid-term process in which, step by step, and in cooperation with the federal states and other groups in society, the risks of climate change will be evaluated, possible need for action noted, the appropriate objectives defined and potential adaptation measures developed and implemented.

On this basis, the most recently appointed inter-ministerial working committee will prepare a plan of action for Germany by the year 2011. Within the scope of considerations on the impact of climate change on transport, the BMVBS is making an active contribution on behalf of the sector navigation and waterways. The objective is to prepare this environmentally friendly and climate-friendly mode of transport for the possible effects of climate change early enough, and to convince the users and operators of the reliability and advantages of waterways in the future.

In this context, the following questions illustrate the issues we will have to tackle in greater detail:

- How can a balanced distribution of water resources be ensured for all users in the river catchment areas?
- Will limitations on navigability occur as a result of extended low water events or also high water levels? What will be the consequences for the distribution of the flow of goods and port management?
- What impact will climate-induced physical changes have on navigation, coastlines and the use of the sea?
- Will the availability of access routes to the German seaports be hampered by more frequent occurrence of storms and storm tides?
- What impact will there be on coastal protection and dyke safety?
- Further issues concern the dynamics of sediments in the sea and inland waters. Will pollutants be distributed differently? Will it be necessary to adapt dredging and maintenance strategies? Will it be necessary to modify waterway engineering concepts for the estuaries?
- To what extent are subjects requiring ecological protection, vegetation and fauna in and near the waterways affected? What action can be taken here?
- How will tourism in coastal areas change? Will more people spend their holidays at the North Sea and the Baltic Sea if weather conditions become warmer? Will there be an increase in recreational navigation?

In order to process these issues and to be able to give appropriate answers to questions from politics, stakeholders, operators and users of the waterways, who as a result of the increase in extreme water levels in recent years are demanding more dependable statements on the reliable future use of waterways and ports, the BMVBS already launched an initiative in the year 2007 with the title “Meeting the Challenges of Climate Change – Navigation and Waterways in Germany”.

In January 2007, in an initial phase, our government research institutes, the National Meteorological Service of Germany (Deutscher Wetterdienst, DWD), the German Maritime and Hydrographic Agency (Bundesamt für Seeschifffahrt und Hydrographie, BSH), the German Federal Institute of Hydrology (Bundesanstalt für Gewässerkunde, BfG) and the German Federal Waterways Engineering and Research Institute (Bundesanstalt für Wasserbau, BAW), were commissioned to compile a report on the current status of climate research and to evaluate this with regard to possible consequences for maritime and inland navigation. The conclusion of this report was published by the BMVBS in February 2008. The report provided fundamental information on climate change and on the sector navigation and waterways, which was integrated into the German Strategy for Adaptation (DAS).

One important finding of the report was that, contrary to the trend for air temperatures in Central Europe, the regional climate models still show contradictory results for the future development of precipitation and water balance. There is scientific consensus that in order to deal responsibly and appropriately with the existing uncertainties, assessments for future planning should not be based on individual scenarios or models. On the contrary, it is essential to work with the ranges of values derived from the various existing emission scenarios and climate models (ensembles).

The research programme KLIWAS has been set up with these principles in mind. Groundbreaking experience from the KLIWAS pilot project which was launched in June 2007 under the coordination of the Federal Institute of Hydrology could already be utilised. The pilot project investigated possible changes of the water balance and the resulting runoff for the Rhine, and included economic considerations. Thus, the first results are already available at the start of the overall programme, which is being launched with today's event.

The research programme KLIWAS will deal with the above-mentioned unresolved issues. In a time frame from 2009 to 2013, KLIWAS will create a basis for:

- obtaining better records of changes in oceanographic and hydrological systems and water status (morphology, water quality, ecology) with the variety of existing climate projections required for this task
- specifying the impact on the system "ship/waterway"
- developing options for adaptation.

KLIWAS will be embedded in a networked structure so that the following requirements can be met:

- guarantee of scientific quality, links to new research information from global climate research and practical orientation through a scientific advisory panel
- introduction to practice-related development of options for adaptation through involvement of the Waterways and Shipping Administration (WSV) via a steering group, as well as WSV forums and stakeholder forums
- networking of the projects and orientation around a common objective through programme coordination.

The scientific advisory panel that was appointed on 2nd March 2009 will give support by assisting with the quality assurance throughout the programme and promoting acceptance in the scientific community. It will strengthen contacts with related research projects at home and abroad and contribute experience from neighbouring states. This scientific supervision will strengthen both KLIWAS and the competence of the German Federal Government for tackling climate impacts.

At the coordination level of the programme, a representative of each of the four governmental research institutions involved is responsible for the scientific goals and tasks. Coordination at project management level will be the task of the Federal Institute of Hydrology.

As a major user of the results of the research, the WSV will be involved in KLIWAS planning activities from the start and will provide active supervision for its further development. This will ensure that the requirements of the operative level will be taken into consideration and specific results can be directly integrated into practical applications.

The Federal Ministries cooperate closely on issues of climate protection and adaptation to climate impacts. In particular, fruitful cooperation has evolved with the BMU, BMBF and BMELV. The research programmes and projects of the departments are synchronised and inter-relationships have been established. As an example, I would like to mention the Federal Government's High-Tech Strategy for Climate Protection, the German Strategy for Adaptation to Climate Change (DAS), the KLIMZUG programme, the collaboration with KomPass (Competence Centre on Global Warming and Adaptation), as well as the establishment of the Climate Service Centre. In this way, unnecessary duplication of work can be avoided and an ideal network structure set up.

Naturally we wish to involve many stakeholders from organisations, business, industry and politics. We wish to converse with them and hear their suggestions, comments and recommendations. The heterogeneity of the participants provides an opportunity to compile experience from a wide range of activities on the issues of climate change for our project.

In this context, I would like to emphasise that in spite of its global dimensions the present economic crisis is a temporary problem, as the economy will recover. Climate change, on the contrary, is a phenomenon mankind will be confronted with for many generations to come. The Federal Government's measures for the stimulation of the economy currently provide investment funding for navigation and waterways on a scale which far exceeds the budgetary means previously available. Both the accumulated demand and the current requirements can thus be covered, permitting the implementation of the requirements for future-oriented development of waterways and navigation as a climate-friendly and environmentally sound mode of transport. KLIWAS will provide important decision-making criteria for future planning. Publishing of the results will not be deferred until the end of the five-year period, but these will be forwarded to users during the project period as they become available.

I would like to close by expressing my gratitude for the considerable amount of work that has already been done in the context of the KLIWAS project. The organisation of the First Status Conference concludes the preparatory phase, and the research programme will now commence on a wider scale in the 31 projects. I wish all participants much success.

KLIWAS in the Context of International and National Activities Regarding Climate Change

Harald Köthe (BMVBS) & Almut Nagel (BMU)

1. The Framework of Climate Change Policy

The year 2007 was a pivotal year in climate change policy. The IPCC published its Fourth Assessment Report on climate change with the messages: climate change is indisputable; it is progressing more rapidly than previously known; and climate change policy is urgently required, feasible and affordable.

In March 2007, a meeting of the EU heads of government was held at which they agreed that Europe should adopt a leading role in global climate negotiations. This was more precisely defined at the G8 summit meeting at Heiligendamm in July 2007. The restriction of the global average temperature to a level of less than 2° above that of the pre-industrial period, in order to limit possible negative consequences became the central climate policy objective of the EU. Even if this target – which is considered extremely ambitious, as the average temperature in the last 150 years has already increased by around 0.7°C – can be achieved, we will still have to reckon with consequences for nature, society and the economy.

At the World Climate Conference on Bali in December 2007, delegations from more than 180 states held consultations on a mandate for negotiations for a new global climate protection agreement, as the currently effective Kyoto Protocol will expire in the year 2012. There, the United Nations had warned of an increasing potential for conflict as a result of global warming. It can be expected that climate change will lead to a massive shortage of water and food.

On Bali the developing countries, whose contribution to the causes of climate change are considerably less significant, agreed for the first time also to take action themselves to reduce their greenhouse gas emissions. In order to meet the set targets on the basis of the scientific results from the IPCC, a reduction of greenhouse gas emissions of between 25 and 40 percent by the year 2020 was considered mandatory for the industrial nations. The target is to adopt an agreement on an ambitious, global and comprehensive settlement for the period after 2012 and to accommodate the EU objective from the World Climate Conference in December 2009 in Copenhagen for restricting global warming to a maximum of 2 °C.

The EU reinforces its international position at the cutting edge of climate change policy through its Climate and Energy Package (approved in December 2008 by the European Parliament), which represents a programme unparalleled worldwide for the investment of billions in the struggle against global warming. The EU sees this as a means for reducing the emission of greenhouse gases (GHG) by 2020 by 20 % compared to the year 1990. If it is also possible to reach an international agreement with other industrial and threshold nations, this target could be extended to a 30 % reduction in greenhouse gases. In the same period, the proportion of renewable energy sources, such as sun and wind, should increase by 2020 from 6.4 % to an average of 20%. Furthermore, energy efficiency in the EU should be increased by around 20%. The economy should be pointed towards an environmentally friendly course with pollution rights ("emissions trading") and the Eastern European countries should receive support in renewing their power stations which are outdated and extremely harmful to the environment.

The expectations for the World Climate Conference which will be held in Copenhagen from 7th–18th December 2009 have risen considerably, in particular with the change of policy in the USA with the new President Obama. The goal of the negotiations there will be – both for industrial and developing countries – to reach agreement on joint action to tackle climate change after the year 2012 when the Kyoto Protocol expires. The result should be a climate protection agreement that is binding for as many countries as possible and includes the following key points:

- a long-term global target for reduction of emissions
- reduction targets for industrial nations that can be monitored and compared
- reduction measures for developing countries
- financial and technical assistance for developing countries both for the reduction of emissions and for adaptation to the impact of climate change.

2. A Framework for Climate Change Science and the Role of the World Meteorological Organization (WMO)

The WMO is a special organisation of the United Nations, with headquarters in Geneva, which was founded in 1950. It is the global organisation for National Meteorological and Hydrological Services (NMHS). In Germany the primary specialist partners on a national level are the National Meteorological Service of Germany (DWD) and the Federal Institute of Hydrology (BfG), where the Secretariat of the International Hydrological Programme (IHP) of the UNESCO and the Hydrology and Water Resources Programme (HWRP) of the WMO with the Global Runoff Data Centre (GRDC) are located.

The WMO is one of the parent organisations, alongside the UNEP (United Nations Environment Programm), for the Intergovernmental Panel on Climate Change (IPCC) which was founded as a consequence of the Second World Climate Conference (WCC-2). The WMO is the home of the IPCC Secretariat in Geneva and shares the expenses with the UNEP.

Through the Federal Ministry of Transport, Building and Urban Development (BMVBS) Germany is the third-largest contributor to the WMO, after the USA and Japan. The annual contributions for Germany in 2008, 2009 and 2010 amount to 8.44 % or approximately 3.3 million EUR.

The WMO functions as coordinator for the WCP (World Climate Programme) which was initiated in 1979 as an outcome of the 1979 First World Climate Conference. This programme has a total of four components with the WMO having sole responsibility for the climate data and climate monitoring programme and the climate applications and services programme. The third component deals with the impact of climate change and is jointly under the aegis of the UNEP, while the fourth pillar is borne by the World Climate Research Programme (WCRP), which besides the WMO, is also supported by the organisations IOC (UNESCO Intergovernmental Oceanographic Commission) und ICSU (International Council for Science).

The Global Climate Observing System (GCOS) was also founded as an outcome of the Second World Climate Conference in 1992, following the realisation that an adequate global database is a prerequisite for all climate monitoring. This is jointly supported by the WMO, UNEP, ICSU and IOC, although the WMO is responsible for the largest share of this programme.

The GCOS Secretariat also has its headquarters at the WMO in Geneva. The GCOS deals with the atmosphere, the oceans and land surfaces. The GCOS is the contact partner for the UNFCCC (United Nations Framework Convention on Climate Change) for questions of systematic monitoring.

The Third World Climate Conference will take place in Geneva from 31.08.–04.09.2009. Germany will be a participant (coordination by the German Meteorological Service). A declared goal is the establishment of the Global Framework for Climate Services (GFCC) as a system for networking globally available capacities and using them for the benefit of less developed countries. There is continuing worldwide demand for a networked system for the exchange of information in the field of climate monitoring and research. If a recommendation is made for setting up the GFCC, decisions may then follow in December 2009 at the World Climate Summit in Copenhagen (COP 15).

3. Activities in the Sector Navigation, Waterways and Ports

The Large Cities Climate Leadership Group – known as C40 – was founded in partnership with the Clinton Climate Initiative (CCI), which was launched by former US President Bill Clinton in 2006. The goal of the C40 group is the reduction of CO_2 emissions in cities in all sectors. Under this umbrella, the World Ports Climate Initiative was founded, taking as its motto "World Ports for a better climate". The WPCI then hosted the World Ports Climate Conference in Rotterdam on 11th July 2008, at which 55 world ports approved a declaration and established the Clean Air Programme for Ports by which specific recommendations and tools are available to make an effective contribution to climate protection.

Measures effective for climate protection for maritime navigation are negotiated at a global level through the IMO (International Maritime Organisation). In October 2008, at Germany's initiative, the IMO decided that from 2012 onwards only low-sulphur fuels with a maximum sulphur content of 3.5 %, and from 2020 onwards not more than 0.5 %, may be used. Although shipping is already a climate-friendly transport mode – responsible for only about 2.7 % of the CO_2 of anthropogenic origin – further measures for the reduction of fuel consumption, and thus a reduction in the emission of greenhouse gases, are being studied and striven for. Furthermore, negotiations are taking place regarding the involvement of shipping in emissions trading.

PIANC (International Navigation Association), the association which has been the specialist platform for the development of infrastructure for waterways and ports on a global level since 1885, published a review of the possible impact of climate change on this sector in ocean and inland areas (PIANC EnviCom Task Group 3: Waterborne transport, ports and waterways: A review of climate change drivers, impacts, responses and mitigation) in May 2008 under German direction.

PIANC also represented the interests of the waterway sector at the Fifth World Water Forum which took place in Istanbul from 16.–21.03.2009. This involvement was mentioned in the ministerial declaration which expressed the intention that, particularly in the inland sector, navigation should receive support and undergo further development with regard to energy saving and energy efficiency and for furthering the objectives of climate protection. Specific activities will take place on a regional level, such as those of the Central Commission for Navigation on the Rhine (CCNR), which hosted a conference under German presidency on the subject of climate change and navigation on the River Rhine on 24./25.06.2009 to determine the path for the future.

On 4th February 2009, the European Commission passed the Green Paper "Towards a better integrated trans-European transport network at the service of the common transport policy" – TEN-T [(COM(2009) 44]. This stresses that the climate protection targets are a standard for top-priority transport networks. With this in mind, the TEN-Ts should be examined with regard to their vulnerability to consequences of climate change, and possible adaptation measures should be evaluated so that the new infrastructure is "climate-change-proof". The integration of climate change issues is also an explicit task for other EU directives with relevance to navigation (e.g. Water Framework Directive, Flood Protection Directive and Marine Strategy Directive).

The European Commission has introduced the term "climate-proofing" to the debate, meaning that the sustainability of investments should be guaranteed for their entire life cycle under the impact of climate change, a topic that will play a part in future planning processes.

The framework for action for adaptation to climate change has been defined for the EU member states, for all sectors, by the European Commission in the White Paper "Adapting to climate change: Towards a European framework for action" (COM(2009) 147, 1st April 2009). The five pillars of the White Paper consist of the following:

- development of the knowledge base, research
- integration of adaptation aspects into Community policies with the aim of reducing vulnerability in the sectors health and social policy / agriculture / biodiversity and ecosystems / production and infrastructure
- financing
- cooperation with the member states
- adaptation to climate change in external relationships of the Community (cooperation on development) and in international climate change negotiations.

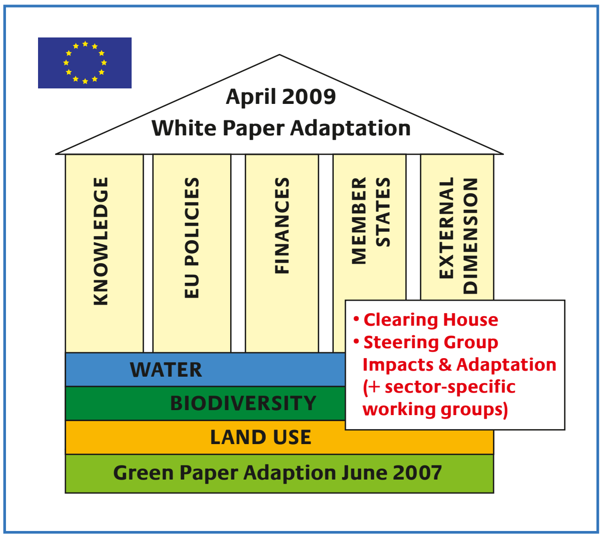

Fig. 1: Overview of EU adaptation strategies

To promote the development of the knowledge base, the European Commission proposes setting up a European clearing house which would compile information on the impact of climate change, the vulnerability of specific sectors or regions adaptation strategies and measures.

The research programme KLIWAS is the response to the need for the development of a knowledge base for the sector navigation and waterways in Germany. KLIWAS is thus also an important component of the German Strategy for Adaptation to Climate Change (DAS) which was approved by the German Federal Government on 17.12.2008.

4. The German Strategy for Adaptation to Climate Change (DAS)

The long-term objective of DAS is to create a framework for national adaptation in order to reduce the sensitivity/vulnerability of natural, social and economic systems to the impact of climate change, and to maintain or increase their ability to adapt to climate change. The DAS pursues an integrative approach for the evaluation of risks and needs for action, supports a sustainable development and mirrors Germany's responsibility on the international scene. It is oriented around the following principles:

- openness and cooperation
- knowledge basement, flexibility and focus on prevention
- subsidiarity and proportionality.

The fields of activity of the DAS are:

- Human health, construction, water/water management, soils, biological diversity, agriculture and forestry, fishing industry, the energy sector and financial management, transport, industry/business and tourism.

Cross section topics of the DAS are:

- Spatial, regional and development planning and civil protection and disaster assistance.

Most of the fields of activity and cross section topics of the DAS are clearly relevant to the theme of water and will thus benefit progressively from the research results produced by KLIWAS. One major challenge is how to react to the uncertainties which are, for instance, related to the current climate projections on the development of precipitation and water balance in coastal and inland waters. Especially in the observation of locally restricted scales, the uncertainties of the projections are increasing. Through its research contents, KLIWAS will address these present uncertainties, create an

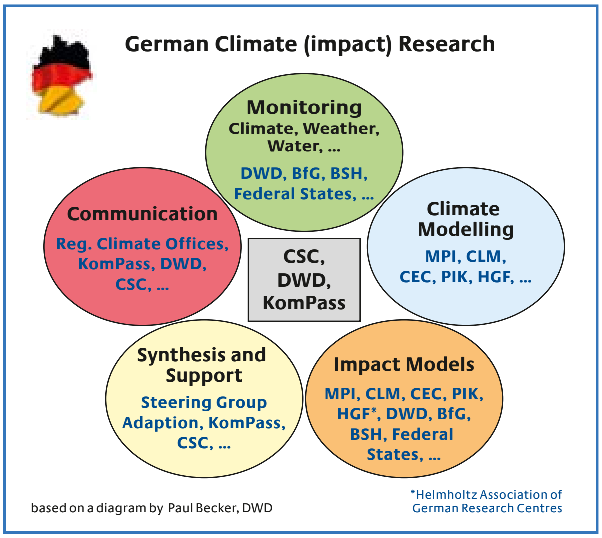

Fig. 2: Overview of German climate (impact) research

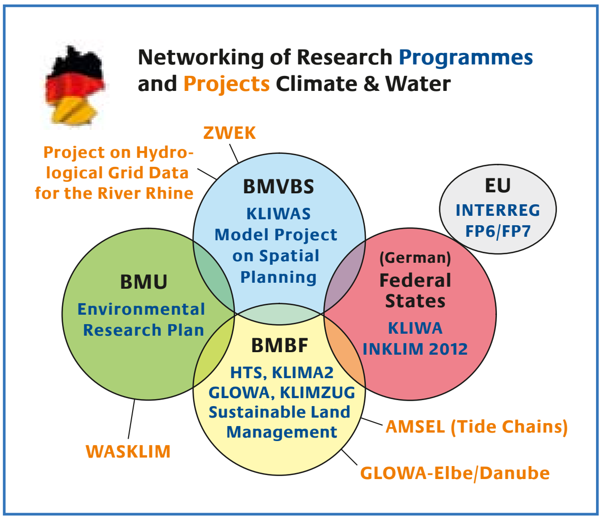

Fig. 3: Networking of research programmes and projects in the field of climate change /water. (Note: the figure does not claim to be exhaustive)

improved hydrometeorological basis for Germany and provide, with the available climate and runoff models, an overall view which includes the morphology, water quality and ecology for the navigable waterways under consideration.

5. Integrating KLIWAS into the Climate Research Landscape

Alongside the government research institutions, the National Meteorological Service of Germany (Deutscher Wetterdienst, DWD), the German Maritime and Hydrographic Agency (Bundesamt für Seeschifffahrt und Hydrographie, BSH), the German Federal Institute of Hydrology (Bundesanstalt für Gewässerkunde, BfG), KLIWAS is an important player in the developing landscape of climate research and climate change research in Germany and internationally. The existing research institutions must find their way to good, mutually complementary alliances in which the fields of climate modelling and climate impact modelling, monitoring, synthesis, support and communication in agreement with the existing competence areas must be developed effectively.

Successful networking of the research programmes and projects which are being carried out by the different departments, the federal states and the European Commission in the field of climate change will be important for achieving the maximum possible synergy with the budgetary means that are being invested. With this in view, KLIWAS will cooperate with the following departments: Federal Ministry of Transport, Building and Urban Development (BMVBS), Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), Federal Ministry of Education and Research (BMBF) and Federal Ministry of Food, Agriculture and Consumer Protection (BMELV). The BMU is funding a KLIWAS project on water quality. The agreement with the federal states will be processed through the government research institutes of the BMVBS with cooperation on a regional level. A scientific advisory panel with international membership will round out and purposefully supplement these networking arrangements.

6. Looking to the Future

In the next phase of DAS, a "Plan of Action for Adaptation" will be drawn up in close cooperation with the federal states and presented to the Bundestag and the Bundesrat by 2011. An interministerial working group has been appointed to prepare the plan of action on the federal level under the auspices of the BMU. The interministerial working group should also consolidate the initiatives of the government departments and supervise and help to shape the process of dialogue and participation that is envisaged for the adaptation strategy, with the objective of arriving at a conceptually consistent approach for the German Federal Government. The following steps will be necessary:

(1) Principles and criteria for the prioritising of the required actions

(2) Prioritising of the measures of the Federal Government

(3) Overview of specific measures of other players

(4) Statements regarding funding, especially through integration of the adaptation into existing funded programmes

(5) Conceptual proposals for monitoring achievements

(6) Defining the next steps in the further development of the strategy.

KLIWAS will make its contribution here, on the one hand, by enabling the identification and initiation of the measures required for securing the environmentally friendly and climate-friendly mode of transportation ship/waterway under climate change and, on the other, by enabling new knowledge to be made available in other spheres of activity regarding:

- the future development of sea level at German coastlines
- the water balance and runoff events in the large German river basins
- future water management on regulated, navigable waterways and canals.

Instruments for Interaction Between Regional Stakeholders

Hans von Storch (GKSS) & Insa Meinke (NKB)

Even with a successful climate policy and a considerable reduction in CO_2 emissions, we will still require information about the transregional and local impact of climate change of anthropogenic origin in order to develop suitable adaptation strategies (Stehr and von Storch 2008). On the basis of our experience, the following essential framework conditions should be monitored (von Storch and Meinke, 2008):

Generally, the stakeholders, including the media and the general public, interpret science as they view it from their respective socio-cultural contexts. Scientific knowledge undergoes several stages of transformation before it enters public awareness. This transformation is reshaped by subjective interests that may be both political and economic. In order to trace this type of transformation in detail, the social and cultural sciences must be involved in the process (von Storch, 2009 a, b). This was the motivation for founding an excellence cluster, the "Integrated Climate System Analysis and Prediction" (CliSAP) at the University of Hamburg, in which the Max Planck Institute for Meteorology, the Institute for Coastal Research of the GKSS Research Centre in Geesthacht and the German High Performance Computing Centre for Climate- and Earth System Research (DKRZ) are participants. At the KlimaCampus in Hamburg, meteorologists, marine scientists and ecologists cooperate closely with other disciplines – with social and economic experts as well as journalistic experts and peace researchers.

Comprehensive analyses of regional and local climate conditions and the impact of climate change, however, are not the only scientific tools required. In addition, foundational knowledge must be communicated to the general public – about natural climatic variations, the extent to which climate change has anthropogenic causes and the relationship between causes, scenarios and the uncertainties in the latter. So that we can provide an all-round advisory service for our target group (government authorities and institutions which are responsible for and interested in coastal management and measures), we have created the database CoastDat (www.coastdat.de; Weisse et al., 2009) which contains detailed datasets of marine weather conditions from the last six decades (including storm tides, wave heights and wind speeds) for the North Sea coast, along with possible future conditions (scenarios) for the next 100 years. In this context, studies have also been carried out regarding the consistency between current climate change and the climate projections for the future (Bhend and von Storch, 2007, 2009).

We as climate scientists share the apprehensions of the stakeholders and the wider general public only to a limited extent. Some of the existing fears are not based on rational premises, but are characterised by irrational anxieties. However, since these partially dominate the social arena, they nonetheless affect political decision-making processes. Scientists must be aware of the full range of influences to which public opinion is subject (von Storch, 2009 a, b).

A further key point which is of major practical significance is the use of a precisely chosen vocabulary. The fact that scientific terms may have varying meanings is not the only problem – these are usually only slightly different, although occasionally the differences may be significant. The use of "colloquial" scientific language also hinders communication and renders it ineffective. Bray and von Storch (2009) carried out a study on this problem area using the example of the terms "prediction" and "projection". More than 30 % of scientists were using the terms incorrectly.

Two exemplary regional initiatives in Northern Europe focus on the necessity for regional research:

In the Baltic Sea region, more than 80 scientists from 13 countries have prepared an investigative report similar to those of the IPCC on the subject "Climate changes and their impact on terrestrial and marine eco-systems in the past, present and future". "BALTEX, The Assessment of Climate Change for the Baltic Sea Basin" (BACC team of authors, 2008; http://www.baltex-research.

eu/BACC/) was adopted by the Helsinki Commission (HELCOM) in March 2007 and is being used as a basis for political decision-making processes in the Baltic region. (http://www.helcom.fi/stc/files/Publications/Proceedings/bsep111.pdf).

A similar project has recently been initiated for the metropolitan region of Hamburg. The first results will be published in November 2009 and the final report is planned for the end of 2010.

In order to further mutual exchange of concepts, misgivings, questions and knowledge between the scientific world and the general public in the region, the North German Climate Office ("Norddeutsches Klimabüro") was founded in 2006 (http://www.norddeutsches-klimabuero.de). Other regional offices have been set up, at the Karlsruhe Institute of Technology for the region Southern Germany, at the Helmholtz Centre for Environmental Research UFZ for the region Central Germany and at the Alfred Wegener Institute in Bremerhaven for the Arctic Regions and for sea level rise (Schipper et al., 2008). At the same time, a national "Climate Service Centre" is being set up at the GKSS research centre in Hamburg, with the participation of several German Federal Ministries, and institutions such as the National Meteorological Service of Germany (DWD) or the German Federal Environment Ministry are providing support for the increase of our knowledge about regional climate change in Germany.

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A2 KLIWAS – Research Tasks and Objectives of the Programme

The KLIWAS Research Programme – Key Points and Introduction to the Research Tasks

Sebastian Kofalk (BfG) & Hans Moser (BfG)

1 Introduction

The management of river catchment areas and water resources management depend in a variety of ways, directly and indirectly, on climate. The climate projections that are presently available suggest that there may be far reaching consequences for the system of inland and coastal navigation, of which the most important segments are waterways, the shipping fleet, ports and the economic sector which relies directly on the mode of transportation "waterway". However, major uncertainties still exist with regard to (1) the character of climate change, (2) its consequences for the hydrological system of the coastal and inland regions and (3) the sensitivity of the water quality and water ecology and of inland navigation and other waterway users.

At present there is a great deal of interest in the topic of climate change on the part of the media. At the same time, there is noticeable discrepancy between the scientific mission and the perception in the media and in society. Climate (impact) research produces results for "projections", "scenarios", "model chains" and "uncertainty" and discusses these in the light of all scientific results. On the other hand public perception is characterised by catchphrases such as "climate collapse", "climate catastrophe", "drought" and "flood". Single weather events, such as the dry year 2003, and individual research results are given absolute value and referred to as a standard for adaptation measures.

As a result of this discrepancy, contradictory surveys and viewpoints on the impact of climate change develop which also play a role in planning processes. In view of this fact and of the debate in society, the following starting points for the research programme KLIWAS *The Impact of Climate Change on Waterways and Navigation – Options to Adapt* should be mentioned:

- scientific statements confirming that climate change is progressing more clearly than hitherto expected, with consequences that must still be more precisely specified (IPCC 2007)
- questions from politics, representatives of industry, operators and users of the waterways, who because of a seeming increase in the frequency of extreme water levels in recent years, expect dependable statements from researchers on the reliable, future use of the waterway and ports
- the necessity for the WSV (German Federal Waterways and Shipping Administration) to have a reliable basis for current and future procedures and for providing answers to the question as to which of these might be necessary for measures for adaptation to climate change, and when, in order to be able to plan for future demands that will be made of ships, navigational routes, spatial order at sea, offshore wind energy and warning services
- Not least should we mention the preliminary research by the DWD, BSH, BfG and BAW which, in some cases, have already been carrying out research for many years on the subject of climate change, independently or in various research alliances (GLOWA-Elbe (Quiel et al. 2008), ZWEK (Becker et al. 2008), KLIWAS Pilot Project "Hydrology and Inland Navigation" (see chapter B). Their activities have demonstrated that statements based in individual results that have not been adequately tested in the relevant specialist field cannot be used as a foundation for long-term, economically acceptable measures for adaptation. This is true of many sectors and not merely the maintenance and construction of waterways.

2 Challenges and Key Points of the Research Programme

Departmental Research and Political Advisory Services

Modern climate research has made it possible to discern human causes for climate change and to describe conceivable changes in important climate parameters in the form of future projections and scenarios. Following a long period in which climate protection was in the foreground, there is now increasing discussion on adaptation to climate change, i.e. the protection of people from the consequences of a possible change in climate. In this respect, it is necessary to investigate both the risks of the effects of climate and the appropriateness of proposed measures or of strategies that are still to be developed.

These challenges to the scientific world and to society in association with climate change and adaptation are examples of the tasks which the German Council of Science and Humanities assigns to departmental research institutions (BMBF 2007): "Departmental research operates at the interface of science and politics. It must address current questions of a social, technological or economic nature, identify the major challenges for the society of tomorrow and draw up recommendations for possible courses of action to be taken by the government. It is interdisciplinary in its conception and provides services for the transfer of knowledge from the scientific system to the user system and vice versa. It must therefore operate within diverse fields of tension which are characterised by the divergent rationalities of science and politics." These guidelines lead to the strategy and the other key points of the KLIWAS research programme. The strategy of the BMVBS includes three consecutive steps in political advisory work:

1. The recording and analysis of a span of regionalised climate projections as a result of the combination of different global and regional climate models (ensembles)
2. Analysis and assessment of the changed hydrological and oceanographical situation, the vulnerability of the mode of transport (navigation) and further ecosystem services of rivers and coastal waters
3. The development and analysis of potential adaptation measures as the main objective of the research programme KLIWAS.

With these steps as a foundation, politicians will be in a position to make decisions in the context of social debate.

Ensemble and Multi-model Approach

The uncertainty of the climate projections presently available has been expressed in the Fourth Assessment Report of the IPCC (IPCC 2007). Figure 1 of Christensen et al. (2007) shows how many from a total of 21 global climate models project an increase in mean precipitation values in Central and Northern Europe in 100 years. The remainder of the 21 models identify a corresponding decrease. The white zones (≈ Central Europe) denote the areas for which about only half of the global models used for the A1B scenario show an increase in mean precipitation.

The span of statements on the impact of climate change which results when differing downscaling (regionalisation) methods are applied is demonstrated by the DWD project "Compilation of Datasets for Climate

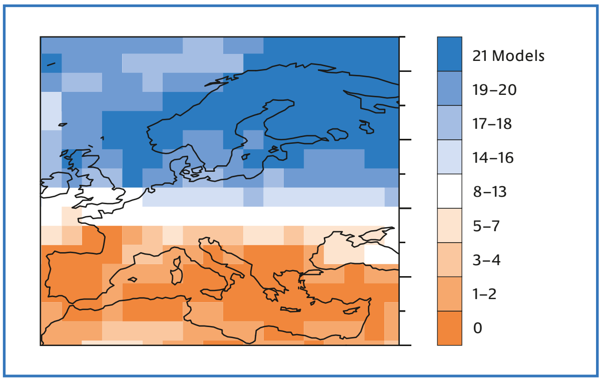

Fig. 1: Number of models which project an increase in mean annual precipitation (comparison of the years 1980–1999 and 2080–2089, multi-model data (MMD), A1B scenario) (Christensen et al. 2007)

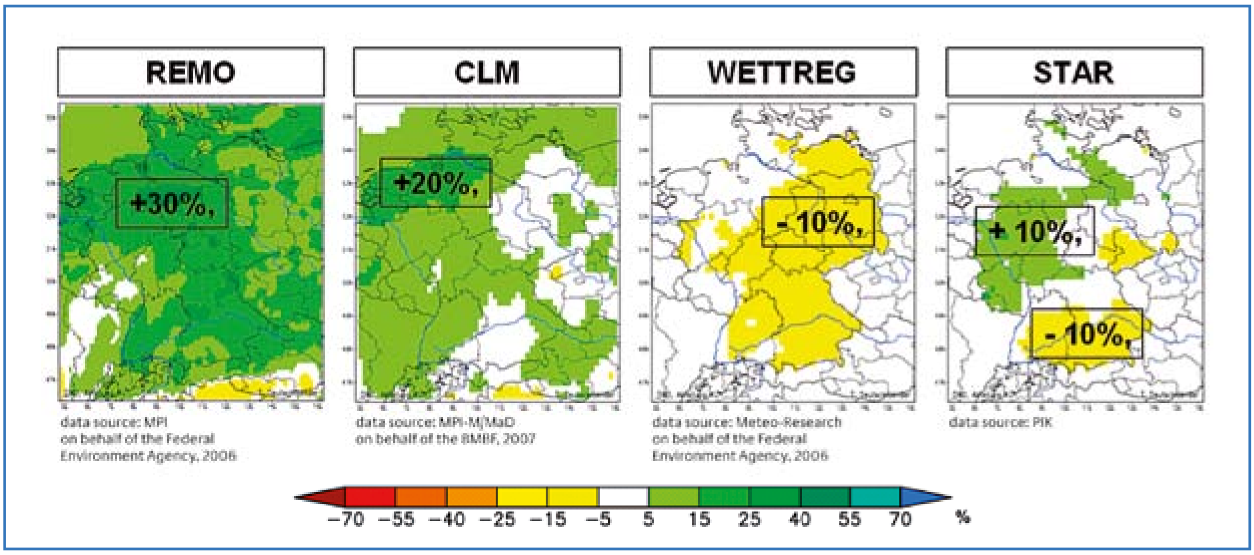

Fig. 2: Relative change in mean precipitation amount in autumn (SON), 2021–2050 compared with 1971–2000. Global model: ECHAM5-T63L31/MPI-OM (A1B Run No. 1) (Becker et al. 2008)

Impact Assessment" (ZWEK, Becker et al. 2008, Figure 2). In this case, the four methods that have mainly been used in Germany up to now were analysed – REMO, CLM, WETTREG and STAR (cf. contribution on Research task 1).

Precipitation and air temperatures vary substantially from region to region, depending on which model has been used. In the assessment of the results on a regional scale, it must also be remembered that uncertainties from the superimposed global model may be passed on to the regional model. How widely the margin will fan out with the processing phase leading to the hydrological parameters in the projection for the period until the year 2100 has now been demonstrated by the first results from the KLIWAS pilot project "Hydrology and Inland Navigation", using the example of the River Rhine (see contributions in this conference volume).

The figures and results illustrate the risk that decision-makers are taking when they rely on information derived from only one climate model. The consideration of results obtained from only one model using varied boundary conditions is thus not adequate for solid political advisory work. On the contrary, it is necessary to include models of various types in an ensemble and to use a multi-model approach, that is, the combination of global or regional models. This is a major task and requirement of the KLIWAS research programme.

At the same time, the existing model uncertainties should be illustrated and made transparent for the users. This requires an accompanying development of assessment methods which permit the user to estimate the quality of the predictions from the various data for different purposes. As an example of these data "package information sheets", and in the interests of quality assurance, we would mention assessments methods such as those developed by Bronstert et al. (2007) with the research project KLIWA "Climate Change and Consequences for Water Management" (Bartels et al. 2004).

Model Chain and System Oriented Approach

The review of the current level of knowledge of climate projections and the possible impact on navigation and waterways in Germany (BMVBS 2008) illustrates that significant gaps in our knowledge must be filled in

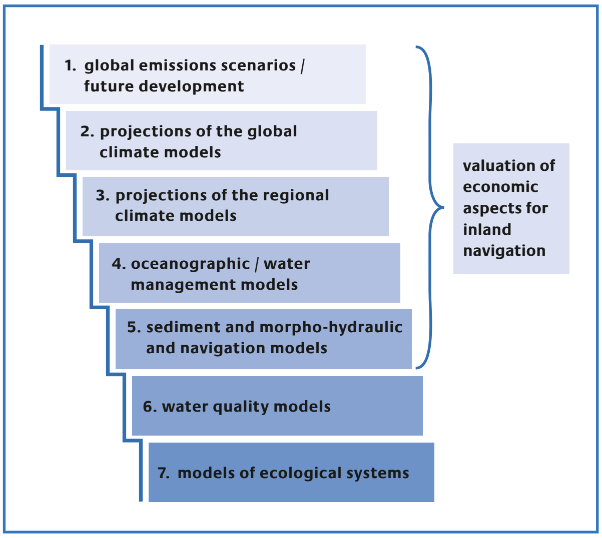

Fig. 3: Model chain for the system oriented approach of KLIWAS

order to be able to monitor the system "waterway" in all its segments concerning its vulnerability to climate change.

Complex models must therefore be set up for river catchment areas, coastlines and the ocean. The results obtained with the ensemble approach to climate and runoff projections are the "driver" for determining and modelling regional climate impact for different condition variables and indicators for the bodies of water or for the individual waterways. This systematic integration of models into a chain will therefore be continued to the level of ecological relationships and water quality (see Figure 3). It will be supplemented by hydraulic-engineering and economic approaches (see contributions by Scholten and Rothstein and by Holtmann and Bialonski in this conference volume). All models are already being used routinely, in some cases for other problem issues, or are being further developed for specific fields. They are an important tool of scientific expertise of the participating research institutions and their partners.

3 Structure of the Research Programme

The research programme consists of 5 research tasks with 30 projects, objectives and work programmes which will be outlined briefly in the following articles of the conference volume. In addition, coordination of the programme is a task in its own right.

Meteorological-hydrological Climate Projections (DWD, BSH)

Research Task 1: Validation and evaluation of the climate projections – provision of climate scenarios for the application on waterways and navigation (Task manager: Dr. Annegret Gratzki, DWD)

Climate Change at the Coasts and Estuaries (BAW, BSH, BfG)

Research Task 2: Changes in the hydrological system of coastal waters (Task manager: Dr. Stephan Mai, BfG, Department M1)

Research Task 3: Changes and sensitivity of the water body state (morphology, quality and ecology) and adaptation options for navigation and waterways (Task manager: Dr. Manz, BfG, Head of Department G3; as of 1.10.2009: Dr. Birgit Schubert, Department G1)

Climate Change in the Inland Zone (BAW, BSH, BfG)

Research Task 4: Changes in the hydrological system: sediment budgets, morphology and adaptation options for inland waterways and navigation (Task manager: Dr. Thomas Maurer, BfG, Head of Department M2)

Research Task 5: Impacts of climate change on structure, ecological integrity and management of inland waterways (Task manager: Dr. Helmut Fischer, BfG, Department U2)

The KLIWAS pilot project "Hydrology and Inland Navigation" was begun by the BfG as a preliminary research phase in January 2007 and has been integrated into Research Task 4. All the other projects will commence during the year 2009 and will be completed in 2013. The alliance of departmental research institutions will cooperate closely with the national and international scientific network. Numerous research institutions will be integrated into the project by means of contractually defined partnerships.

The organisational structure of the KLIWAS research programme includes a steering group at ministerial level. This will agree on basic decisions regarding the scientific concept with the programme coordinators. The scientific advisory panel mentioned in previous contributions (Törkel, Köthe & Nagel) provides quality assurance and offers recommendations to the programme coordinators and the steering group regarding scientific and methodological approaches and on the integration of external cooperation partners into the projects. The programme coordination is made up of a representative from each of the departmental research institutions and a coordination office located at the BfG. The programme coordination group is responsible for the research programme as intended by the alliance. The coordinators of the tasks have drawn up the descriptions of the tasks in collaboration with the project managers. They are responsible for networking and for achieving the objectives and they function as representatives for the tasks.

Important coordination tasks associated with the launching of the programme are the development of internal and external communication (publicity, data management etc.). A communications strategy is one of the significant elements of the research programme. A further element is the networking with other research programmes at the centre of the activities with planning and implementation of many different kinds of events.

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Validation and Evaluation of the Climate Projections – Provision of Climate Scenarios for Application on Waterways and Navigation – A brief Description of the Work planned for KLIWAS Research Task 1

Bruno Rudolf (DWD), Paul Becker (DWD) & Hartmut Heinrich (BSH)

In the context of the KLIWAS research programme, Impact of Climate Change on Waterways and Navigation in Germany, Research Task 1 “Validation and evaluation of the climate projections – provision of climate scenarios for application on waterways and navigation” will include the preparation of a database for reliable assessments of climate change with regard to its impact on the sphere of waterways and navigation. This includes both the compilation of the meteorological and oceanographic reference data on the basis of measurements and the assessment and provision of the reference datasets required for the projects using climate model simulations for a variety of climate scenarios. The task thus covers the user-oriented processing and scientific evaluation of meteorological and oceanographic observation and model data as well as the validation and quantitative estimation of the uncertainties of the climate projections.

In order to quantify the uncertainties, comparisons and assessments of projections from different climate models must be carried out. In addition, various specialised data evaluations are required with a view to obtaining reliable quantification of climate impact for hydrological issues. A multi-model approach is planned for inland water bodies, similar to that already used in the DWD (National Meteorological Service of Germany) project ZWEK (Compilation of Datasets for Climate Impact Assessment) and in the KLIWAS pilot project “Hydrology and Inland navigation” of the BfG. For the coastline and offshore, the DWD will be cooperating with the BSH in an approach with similar methodology, to obtain comparable results for this region.

Background

The ongoing change in climate is most clearly apparent in the form of global warming. Since the beginning of the industrial age more than 200 years ago, the increase of the air temperatures, at first very slight and then gradually intensifying, has been proved categorically by meteorological observations both for Germany and globally. In the last 100 years (1906–2005) the global air temperature has risen by 0.7 °C, and in Germany, by as much as 1.1 °C. The climate projections in the recently published Fourth IPCC Report, which were analysed with a large number of global models of differing complexity, taking into account all significant emissions scenarios for global warming, predict a further temperature increase (change in the average global surface temperature) of 1.1°–6.4 °C by the end of the 21st century in comparison with the period 1980–1999, with a most probable spread being between 1.8° and 4.0 °C. Current regional model statistics predict warming in Germany of between 2.5° and 3.5 °C. In the region of the North Atlantic and its intracontinental seas, a significant rise in water surface temperatures has been observed in recent years. In the North Sea, the anomalies of the monthly averages have at times been well above 2 °C.

Although precipitation is subject to greater uncertainties in terms of observation and prediction than temperature, certain tendencies in the observation data and results for regional climate models can still be identified. The clearest trends in the observation data can be seen for winter, when in southern Europe there has been a significant decrease in precipitation in the last 50 years; in northern Europe, on the contrary, an increase has been recorded. In Germany, in the last 50 years, an increase in precipitation in winter has been observed, but a decrease in summer. Intense precipitation events, especially, have become more frequent and more intense in the south of Germany than 50 years ago. At present, the best regional climate projections show a significant trend towards a drier climate in southern Europe by the end of the 21st century, whereas in northern Europe an increase in precipitation may be expected. For Central Europe (including Germany) there is a tendency towards more frequent and longer periods with low precipitation (particularly in the summer) and also an increasing probability of torrential precipitation that in inland regions could lead to more frequent and more extreme high water events, especially in the winter. There is also debate on the increase in the risk of flooding due of a rise in sea level and a higher frequency of severe storms affecting the German coastal areas. When air temperatures rise, there is an increase in the evaporation rate over moist surfaces. If at the same time, there are periods with low precipitation, coupled with reduced snowmelt as a result of a changed distribution of the winter precipitation regime, there is a greater likelihood of low water in inland waterways, particularly in the summer half-year.

Statement of the Problem

At present, the results of global and regional climate model statistics still contain large uncertainties, above all in the elements most relevant to hydrology and oceanography, such as precipitation and wind. The numerous different models show considerable differences and, for some regions, even contradictory results. Information on the quality of the model that could be obtained by comparison with reliable reference data and quantification of the uncertainties of the projections is often not available, or is not adequate, particularly for regional climate models with a high spatial resolution.

Objectives

The DWD and BSH will provide advisory services for tasks of the BMBVS in matters of meteorology, oceanography and climatology and support them with all available means, data and products. Task 1 is linked to a customised service for impact modellers that will follow further down the model chain.

Top priority will be give to answering the following meteorological and oceanographic problems:

- preparation of suitable gridded datasets on the basis of observation data for the validation of the climate models for the entire catchment areas of the following rivers: Rhine, Elbe, Upper Danube and Oder, including the regions thereof that lie outside Germany
- preparation of oceanographic and maritime meteorological reference datasets for the North Sea and Baltic Sea on the basis of the expanded database
- checking, verifying and determining the error spread for the applied regional and global climate simulations by means of a comparison of the model results in the control period with reference data, i.e., with reliable analyses on the basis of observed climate data
- changes in the precipitation parameters and other relevant hydrometeorological parameters with a view to the navigability of waterways, coastal protection and ground water supplies
- extreme weather events (storms, precipitation, drought etc.) and their influence on waterways, coastlines ad maritime navigation regions
- changes in the atmospheric circulation in the North Sea and Baltic Sea regions and the adjoining North Atlantic and changes in oceanic circulation as a result of altered meteorological driving forces
- evaluation of regional climate models for the period until 2050 or 2100, depending on the model, with a view to applications in the field of water.

The specific objective of this task is to fill the gaps in data and knowledge that are particularly important for reliable quantification of climate impact in the field of water. In the context of the three projects associated with reference data for river catchment areas: “Development of reference data related to river catchment areas”, “Assessment and provision of application-optimised climate projections” and “Reference data and climate projections for the marine region” the task consists of preparing a basis for reliable assessment of climate change and its impact on navigation and waterways in inland areas and at the German coastline, in the North Sea, the Baltic Sea and the Northeast Atlantic. For this purpose the validation and quantitative estimation of the uncertainties of the climate projections are necessary, basic prerequisites. Furthermore, supplementary work of various kinds will be required in the field of user-oriented processing and scientific evaluation of observation and model data. This will include, for example, the acquisition and integration of data from neighbouring countries in order to completely cover the hydrological catchment area for Germany.

The extraction of high-quality reference datasets and of the validation and assessment of the climate projec-

Table 1: Projects for KLIWAS Task 1: Validation and evaluation of the climate projections – provision of climate scenarios for application on waterways and navigation

Proj. No. 1.01	**Hydrometeorological reference data for river basins**
1.01a	Development of spatially/temporally extended climatological reference data for river basins
1.01b	Analysis of climatic changes in the distribution of circulation patterns in Central Europe on the basis of re-analyses and model simulations
Proj. No. 1.02	**Provision of application-oriented and evaluated climate projection data**
1.02a	Formation of ensembles and downscaling of climate project data
1.02b	Postprocessing of climate projection data
Proj. No. 1.03	**Atmospheric and oceanic reference data und climatic projections for coastal and open sea areas**
1.03a	Reference datasets related to meteorology, oceanography and coastal ecosystems
1.03b	Climate projections for the coastal regions and offshore

tions that these permit, along with the provision of statistical results for the quantification of uncertainty of the regional climate simulations for the sphere of activity “navigation and waterways in Germany” will make a significant contribution to the existing BMVBS research programme.

Project 1.01: Hydrometeorological Reference Data for River Basins

Sub-project “Development of Spatially/temporally Extended Climatological Reference Data for River Basins”

Reliable statements on the extent of expected climate change and the necessary analysis of vulnerability are only possible against a background of clearly defined reference conditions. To be able to describe the former it is necessary to have records of observations of the weather or time series for the relevant weather elements that reach far back in time; these must cover the catchment areas of the navigable rivers in Germany, offshore and coastal regions in an adequate spatial and temporal resolution. These series must also be of the highest standards in terms of quality and homogeneity. With regard to statements on inland waters as well as coastal waters and the open sea, and for the atmospheric and oceanic zones, differing scales of space and time are applicable.

Particularly for statistical time series analysis and a possible change in the behaviour of extreme precipitation values, it is essential to have one-hundred-year time series for daily values. Only in this way statistical estimates are able to provide reliable statements on the variability of precipitation. For the assessment and quality assurance of the precipitation data and for the derivation of further important data for hydrological models, such as evaporation and soil humidity, additional parameters including temperature, wind, cloud cover and humidity must be available at a smaller number of locations (climate stations).

The goal is the production of hydro-climatological gridded data which is suitable for the validation and assessment of regional climate models with regard to hydrological requirements in the inland regions (high and low water) and for the statistical analysis of climate for the river catchment areas. This gridded data should correspond to the requirements regarding temporal and spatial cover of the area of interest and fit to the volume and quality of data required.

Meteorological observations with a daily value resolution for the area of the Federal Republic of Germany are hitherto only available for precipitation, and only since around 1961. An enhancement of the database back to at least the year 1951 is urgently required for the application area “high and low water”. As most of the large river catchment areas in Germany also have regions located in other countries. It is also essential that data from these countries is included in the reference datasets. Gridded data with daily resolution are needed for validation of the grid based climate models and for regionally specific assessments. Up to now, daily gridded data is available only for precipitation and only for the area of the Federal Republic of Germany. For applications in the hydrological field, gridded data, at least for air temperatures, is also required with daily resolution. Methods for downscaling of daily data for air temperatures and other meteorological variables must be developed. Besides the enlargement of the database, an improvement in data quality is also needed. Comprehensive validation of the DWD stations was not introduced until 1978. Checking of all data (including the foreign data) must be carried out, particularly for the years before 1978 (e.g. Fuchs et al. [2001], Richter [1995]).

Sub-project “Analysis of Climatic Changes in the Distribution of Circulation Patterns in Central Europe on the Basis of Re-analyses and Model Simulations”

The objectives of the analysis of circulation patterns using an objective weather type classification are to validate global and regional climate models with regard to their ability to realistically simulate weather sequences and to filter out the climate signal with regard to changes in the frequency of certain weather types.

In the latter instance, only weather situations related to extreme events, such as wet or dry periods, or intense precipitation, will be investigated.

The framework for the study includes the enhancement of the time series of the objective weather type classification for the past, on the basis of the ERA40 reanalyses from the ECMWF, and for the future, on the basis of a variety of model simulations (climate projections). This method analyses, compares and interprets the frequency distribution of the weather type classes for different periods of time. For this, the quantitative analysis of correlations between weather type frequencies and the distribution of temperature and precipitation throughout Germany and the neighbouring regions forms a major part of the study.

The evaluation of the plausibility of different climate projections also allows them to be used as a reliable basis for planning principles for impact studies and a safe derivation of future recommendations for action for the operation of federal waterways and for navigation.

The result of the weather type analysis is an evaluation of the ability of climate models to simulate circulation regimes for Central Europe. Furthermore, an analysis is provided of the impact of climate change on weather types in Central Europe and of the precipitation and temperature effectiveness. This creates time series of the objective weather type classes on a daily basis for the period from around 1960 to the end of the projection period which can be referred to for the evaluation of changes in the weather type distribution that have already occurred and that are expected in the future with regard to the frequency of occurrence of significant atmospheric events.

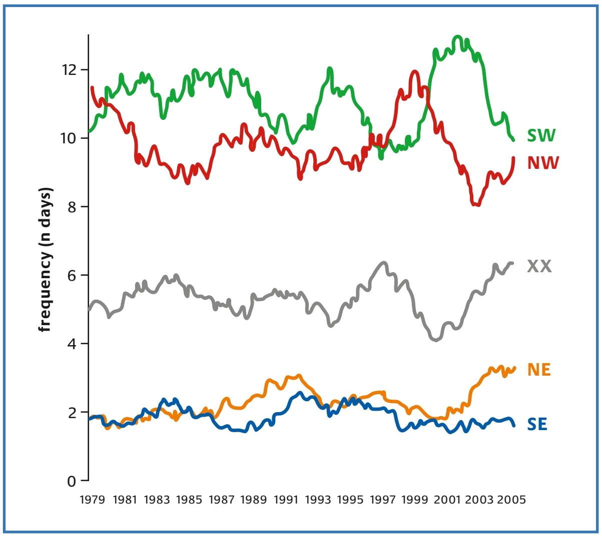

Fig. 1: Temporal variability of wind directions of the objective weather type classification (oWLK) (SW – southwest, NW – northwest, NE – northeast, SE –southeast, XX – not uniform); moving average over 36 months in the period 1979-2005; classified by the GME (Global-model of the German Meteorological Service (DWD)); Riediger (2008)

Project 1.02: Provision of Application-oriented and Evaluated Climate Projection Data

In the past, when carrying out impact studies for climate projections, at best merely a small number of different input datasets were used simultaneously. This has resulted in considerable uncertainties regarding the chronological course of the expected changes. In addition, the quality of the simulated hydrometeorological parameters, which often fluctuates widely, leads to further uncertainties.

The user-oriented processing of climate simulations must take place in accordance with the requirements of impact models. This needs the use of statistically substantiated analytical procedures. Verification of regional climate models for the validation and assessment of the different models is also urgently needed. This is done by comparing the models with each other and with high quality climatological observation data from past years.

The application of the ensemble technique in climate impact modelling is still new. The number of individual, independent model simulations available until recently, was not normally sufficient for use in a probabilistic approach. Instead, it was assumed that all individual simulations were equally probable. Only in

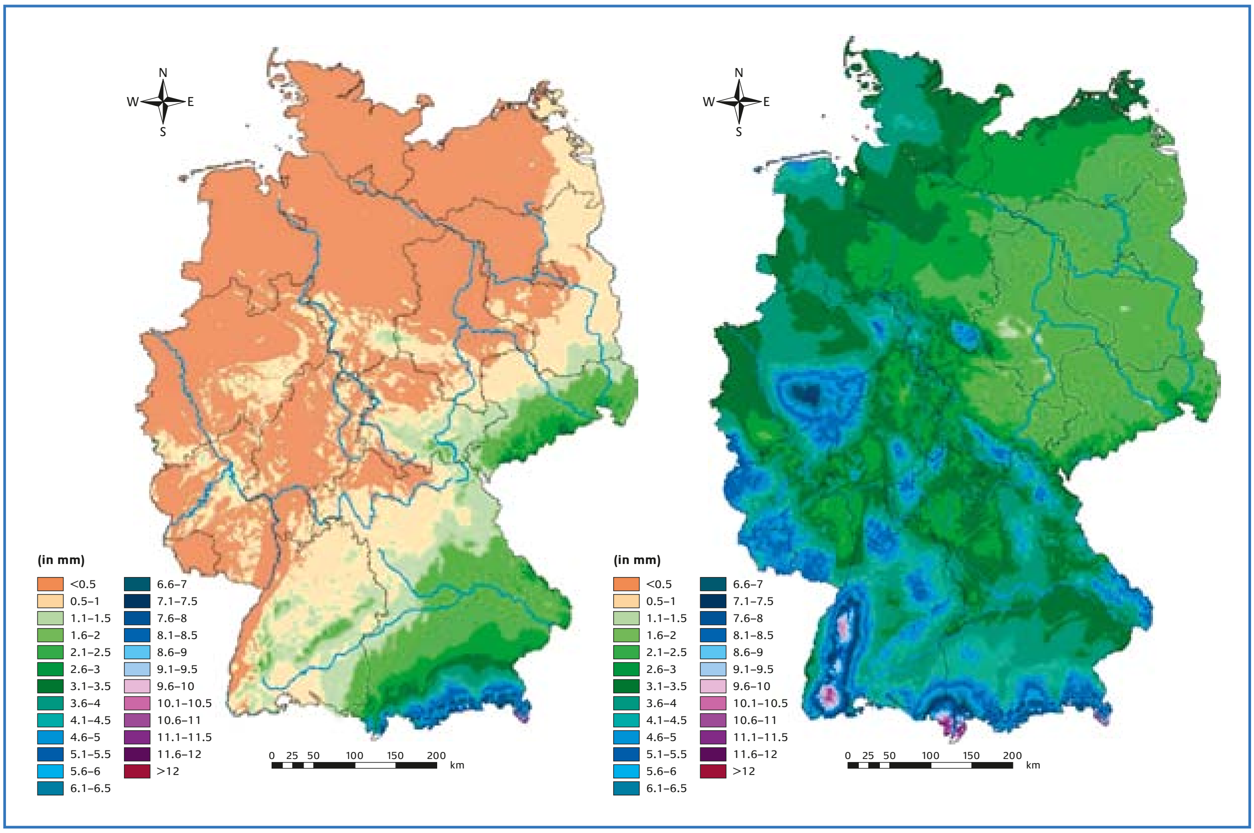

Fig. 2: Mean precipitation distribution for two objective weather types of the oWLK for the period 1979–2005, left: weather types with, northeast flow and anticyclonic structure at 950 hPa geopotential – right: weather types with, southwest flow and high-reaching cyclonic influence; RIEDIGER (2008)

more recent years, has the ensemble concept become the standard approach in this field, thanks to research initiatives such as ZWEK (Compilation of Datasets for Climate Impact Assessment; e.g. BECKER et al., 2008) or the project “PArK Abschätzung regionaler Klimaänderungen” (Probabilistic Assessment of Regional Climate Change) coordinated by the Institute for Meteorology and Climate Research at the University of Karlsruhe. The data from the EU project “ENSEMBLES” which is to be published in the next few months, will bring about a further improvement, necessary for producing sufficiently comprehensive model ensembles.

Also in view of the postprocessing problems, several investigations have already been carried out, and their results will serve as a basis for the development of suitable methods. However, this is true primarily for the aspect of the analysis of extreme values; the postprocessing of climate projection data is still current in science.

Project 1.02 will therefore be divided into the sub-projects “Formation of Ensembles” and “Postprocessing”.

Objectives

For the two sub-projects there are following aims:

Table 2: Matrix of the global and regional climate models initially planned in KLIWAS with the IPCC scenarios used in each case

		Institution	Model	GLOBAL CLIMATE MODELS METO-HC HADCM3Q0	METO-HC HADCM3Q3	METO-HC HADCM3Q16	MPIMET ECHAM 5	CCCMA CGCM3	CNRM ARPEGE	NERSC BCM
REGIONAL CLIMATE MODELS	ENSEMBLES	METO-HC	HADRM3Q0	A1B			A1B			
		METO-HC	HADRM3Q3		A1B		A1B			
		METO-HC	HADRM3Q16			A1B	A1B			
		MPIMET	REMO				A1B			
		CNRM	ALADIN						A1B	
		DMI	HIRHAM				A1B		A1B	A1B
		ETHZ	CLM	A1B						
		KNMI	RACMO				A1B			
		ICTP	RegCM				A1B			
		SMHI	RCA		A1B		A1B			A1B
		UCLM	PROMES	A1B						
		C4I	RCA 3.0			A1B	A2			
		Met.No	HIRHAM							A1B
		VMGO	RRCM	A1B						
		OURANOS	CRCM					A1B		
	CERA	MPIMET	REMO				A1B*, B1, A2			
		CEC	WETTREG				A1B, B1, A2			
		PIK	STAR				A1B			
		GKSS	CLM				A1B, B1			

* different runs — downloaded — coming soon

Sub-project "Formation of Ensembles and Downscaling of Climate Projection Data":

1. Collection and compilation of climate projection time series (see Table 2)
2. Downscaling of hydrological parameters to river catchment areas (monthly and daily precipitation values and air temperature as well as other meteorological parameters for estimating the rate of evaporation and the soil moisture) to a required spatial and temporal resolution of 5 km × 5 km and daily values
3. User-specific data transfer.

Downscaling to the above mentioned resolution should be carried out with the downscaling method REGNIE which was developed by the DWD. Station projections of statistical regional models at certain stations are transferred to the area. The grid point information of the numeric regional climate models, which is coarse at present, is transferred to a higher resolution.

In order to achieve a more reliable estimation of the range of possible future climate changes, the "ZWEK" model ensemble that is currently being used by the DWD in the context of the project will be expanded. The four current runs of the regional models REMO, CLM, WETTREG and STAR were each actuated by Run 1 of the global climate model ECHAM5 for the emissions scenario A1B. This ensemble will be added to as follows:

a. further start runs (at present runs 2 and 3 still exist) of the ECHAM5 model for the emissions scenario A1B (possibly also for other emissions scenarios)

b. other regional models:
e.g. RCAO of the Rossby Centre at the SMHI (interface coupled variant of the regional atmosphere model (RCA) and the regional ocean model (RCO)) with a more realistic reproduction of the past climatic conditions in the area of transition between land and sea (Döscher et al., 2002)

c. additional emissions scenarios:
i. B1
ii. A2

d. (as available) projections using other global climate models (GCM) besides ECHAM5 (e.g. the Hadley Centre GCM)

e. adoption of available climate projection time series, particularly from the EU project "ENSEMBLES"

f. developement of any necessary reference datasets (e.g. ERA40 data from the EZMW; ECA-data from the KNMI).

Sub-project "Postprocessing"

The objective of the sub-project "Postprocessing" is the provision of hydometeorological projection data which is consistent with regard to time and space and is spatially consistent with the river catchment areas being monitored in Germany. The statistical analysis and verification of climate projection time series with regard to the statistical regional climate models is carried out on a station-specific basis.

An extreme value analysis of the climate projections, for instance, with regard to high daily precipitation values and the duration of wet or dry days should be organised with modern statistical procedures such as "peak over threshold" (POT) (Kysely et al., 2008, Früh et al., 2008) or with the help of "structure-oriented time series analysis" (Jonas et al., 2005).

As a pattern for the development of a suitable postprocessing system, methods such as MOS (Model Output Statistics) or PP (Perfect Prog) should be referred to. This approach has been used successfully for numerical weather forecasting for many years to increase the forecasting precision of model predictions. Successful transfer of these methods to climate modelling first requires the analysis of some basic problems. One important example is the question of how to deal with the varying time scales for which climate simulation models are to be evaluated. Presumably the most difficult problem that must be solved will arise from the postprocessing preservation of consistency between the varying individual meteorological parameters without which the operation of complicated impact models is impossible, or possible only with limitations.
The main topics of the sub-project postprocessing are:

1. Derived of statistics for

- checking of the spatial consistency of the meteorological parameters for the river catchment areas
- analysis of the behaviour of extreme values (drought/high water)

2. Evaluation of the climate projection being used, by means of

- comparison of the control runs with observation data (see also sub-project "Downscaling")
- comparison of the models with each other (see, e.g., Figure 3)

3. Optimisation of the quality of the projection data, by means of

- evaluation of suitable postprocessing methods (such as the MOS method) and their typical applications, while
- paying particular attention to retaining consistency of the climate parameters among themselves, as well as their spatial and temporal consistency.

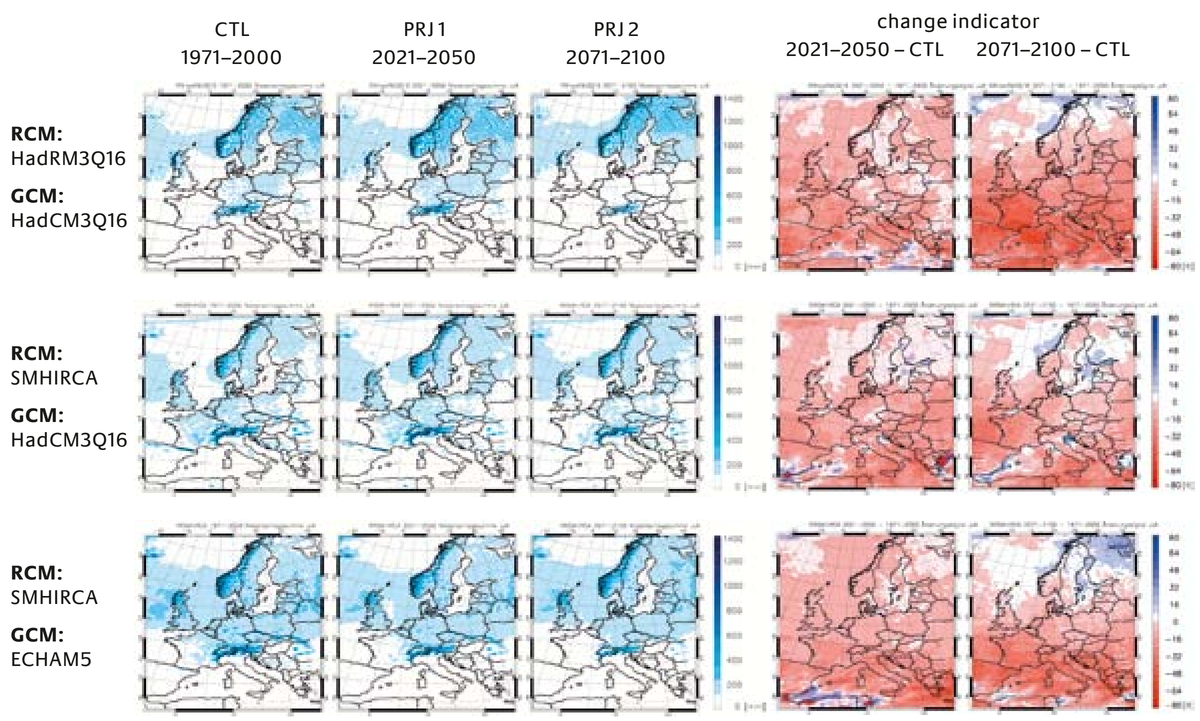

Fig. 3: Variability of the climate signal for precipitation amounts in the summer months (June, July, August) depending on the global and regional climate model used (GCM or RCM). The figure shows the mean precipitation amounts for the control period (CTL) 1971–2000 and the two projection periods (PRJ) 2021–2050 and 2071–2100 as well as the climate signal (right).

Project 1.03: Atmospheric and Oceanic Reference Data und Climatic Projections for Coastal and Open Sea Areas

The objective of Project 1.03 is the development and provision of the complete reference database for the assessment and estimation of climate changes and their impact on maritime navigation, coastal regions and ports. The necessary meteorological, oceanographic and ecosystem reference datasets should be compiled and made available as a standard of comparison for observed and projected changes.

In contrast to inland waters, for which primarily data on precipitation and evaporation is required for statements regarding high and low water events, the investigation of atmospheric and oceanographic circulation, wind strength and direction, storm tides, ocean currents, salt content, air and water temperatures and ice cover is of primary importance in the marine sector.

Sub-project "Reference Datasets Related to Meteorology, Oceanography and Coastal Ecosystems"

The task of this sub-project is the development of a comprehensive reference database for meteorology, oceanography and ecosystems for testing the climate model runs and for estimating the climate changes which will be derived from the climate model simulation for the North Sea, Baltic Sea and North Atlantic.

The archives of the BSH and of the Centre for Global Marine Meteorological Observations (Globales Zentrum für Schiffswettermeldungen – GZS) of the German Meteorological Service provide access to all available meteorological and oceanographic in situ data from the marine sector being investigated (marine weather records reaching back to the first half of the 19th century, data regarding buoys and platforms, aerological data, long time series of water level records, data regarding ice cover and salinity). A comprehensive database of observation data is thus already available for derivation of the atmospheric-oceanographic reference datasets for the German coastal areas, the North Sea and the Baltic Sea and the North Atlantic that are required for the project.

In the North Sea (German Bight) and in the western Baltic Sea the BSH (represented in the Baltic Sea region by the Leibniz Institute for Baltic Sea Research [IOW]) is gathering oceanographic data with the assistance of regular monitoring and through the automatic observation network MARNET. The data is also being routinely collected through R & D installations for offshore wind energy. Monitoring in the German Bight and the western region of the Baltic Sea is organised several times a year. The main focus is on the collection of vertical profiles of temperature, conductivity and optical measurement parameters on a fixed station network.

The observation programme ARGO (Array for Realtime Geostrophic Oceanography) is making a valuable contribution to the oceanic database. ARGO was set up in the year 2000 as a research programme for the purpose of efficiently linking observation capacities in the ocean with climate monitoring on an international basis. It uses profiling floats to record changes of temperature and salinity in the upper 2000 metres of the world's oceans and to make them available in real time. The ARGO programme is of strategic importance in the climate monitoring of national bodies of water as it provides the observation for the identification of changes in the Atlantic and their impact on the North Sea (see, for example, "the problem with the Gulf Stream" as a result of the expected influence of the driving forces "thermohaline circulation").

Sub-project "Climate Projections for the Coastal Regions and Offshore"

The available regional climate models are to be studied and assessed with regard to their suitability for determining the impact of climate change on maritime issues. In accordance with the clearly diverging spatio-temporal requirements for coastal areas and the open sea, various implementations must be identified for the different problems. In addition, regional models must be used to make estimations of the changes in oceanic conditions over the North Atlantic, the North Sea and the Baltic Sea. The use of models with different spatio-temporal resolution for large areas of the oceanic regions will be unavoidable here.

The differing implementations also define a possible spread for the reliability of statements on future events. The assessment of the regional models is carried out by comparing the test runs of the models with the reference datasets produced in the sub-project on the basis of observation data.

The objective of the project is the development of a database adjusted to take account of these problems for describing the future climatic conditions over the North Atlantic, the North Sea and the Baltic Sea. The time series of meteorological and oceanographic parameters (especially air and water surface temperatures, barometric pressure, wind, water levels, sea swell) from stations at fixed locations (coastal and island stations, platforms, buoys) and for defined grid datasets for selected maritime regions should enable conclusions to be drawn regarding mean values, probabilities and extreme conditions. An improvement in the use of impact models for climate research in atmospheric and marine fields is planned.

Looking to the Future

The specific project work in Research Task 1 will commence in mid-2009. This task will lead to the improvement of methods and principles for the assessment of projections and will expand our knowledge of the expected climatic change and its impact on people, the environment and the economy. For hydro-meteorological issues, the DWD sees itself primarily as a service provider for the tasks and projects. The DWD (atmosphere) and the BSH (oceans) will work in partnership.

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Changes in the Hydrological System of Coastal Waters – KLIWAS Research Task 2

Stephan Mai (BfG), Hartmut Heinrich (BSH) & Harro Heyer (BAW)

1 Introduction

The projections for climate change prepared by the IPCC (2007) for various scenarios of global emission of greenhouse gases IPCC (2000) seem to indicate the probability of acceleration of global increase in ocean and sea temperatures and an accompanying acceleration in the rise of sea level. There is still discussion on a possible shift in the tracks of storms and of their intensity as a result of climate change for the Northeast Atlantic and the adjacent shelf seas such as the North Sea and the Baltic Sea (von Storch et al. 1998). Projected onto a large scale, these climatic impacts of the emission of greenhouse gases will also result in a transformation of the hydrological system of German waterways in coastal waters and estuaries. In the scope of the KLIWAS research programme, this hydrological change is being studied by the higher federal authorities, the National Meteorological Service of Germany (DWD), the Federal Waterways Engineering and Research Institute (BAW), the Federal Institute of Hydrology (BfG) and the Federal Maritime and Hydrographic Agency (BSH), with the aim of downscaling the projections made by bodies such as the IPCC for application to German waterways and coastal regions.

2 The Background to Climate-induced, Quantitative Changes in the Condition of Coastal Waters and Estuaries

The hydrological condition of coastal waters and estuaries is determined by the atmospheric forces on the open sea, that is, wind and barometric pressure and by oceanographic conditions, i.e., water level, current, salinity and temperature. The discharge of headwaters is an additional influencing factor in estuaries.

Changes in the atmospheric forces and the oceanographic constraints caused by global climate change will lead to regional changes in hydrological conditions of the German coastal waters of the North Sea and the Baltic Sea and their estuaries. The rise in the mean sea level of the oceans as a result of climate change will continue in the form of a rise in average sea level of the continental shelf seas. Especially at the North Sea coast, with its tidal influences, the consequences of the rise in sea level are a special point for debate (Duwe 2000, Plüss 2004). The change in wind condition and discharge of inland rivers caused by climate change will cause considerable reactions in the salinity, thus affecting the mass structure in the North Sea (Schrum 2001, Kauker 1999 and Heyen & Dippner 1998), currents (Grabemann et al. 2004) and sea swell (Grabemann & Weisse 2008). Besides the changes in the mean oceanographic/hydrological situation, the climate-induced changes of atmospheric circulation, especially of the altered tracks of cyclones and the intensifying of the west wind situations, will furthermore lead to a greater frequency of extreme events. In this context there will not only be an increased probability of extreme tidal water levels, but more extreme sea swell conditions can also be expected (Mai & Zimmermann 2004; Outzen, Herklotz, Heinrich & Lefebvre 2008). A summary of further changes in the hydrological system of marine waterways as a result of climate change can be found in Moser et al. (2008).

The climate-induced hydrological changes in coastal waters and estuaries have both a direct and an indirect impact on navigation and, thus, also on the management of federal waterways in Germany (Moser et al. 2008).

For instance, greater frequency or increase in the intensity of storms and storm surges as a direct result of changed hydrological conditions would hamper the usability of German marine waterways and impede access to German ports. In particular, more intensive sea swell would lead to an increase in stress on off-shore structures, navigational signs such as lighthouses and markers, transversal and parallel structures such as longitudinal river training structures, groynes and bank protection structures and other structures for sea-going navigation and coastal engineering, such as quays or locks and barrage gates. This increased stress would result in additional cost and effort for the maintenance and repair of the above mentioned facilities.

If storms occur more frequently, pilot transfer will, for example, also be hindered, resulting in higher deployment of personnel. Besides the expected climate-induced intensification of extreme hydrological events, the expected change in the mean hydrological conditions that is expected to accompany climatic changes will directly affect construction measures in coastal areas and in the estuaries. The changes in tidal levels will probably result in the necessity for adjustments of groynes and training structures, for example with regard to the required crest height. An anticipated change in the entry of the tidal wave to an estuary will call for adjustments, especially in schedules for tide-dependent harbour approach.

The impacts of changing hydrological conditions will affect the morphology, water quality and ecology and are dealt within the overview of Research Task 3 by Manz et al. (see contribution in this volume).

Figure 1 depicts the association of direct and indirect climate impact on coastal and estuarine regions with Research Tasks 2 and 3. The diagram shows the increasing complexity of individual sub-processes and the related increasing uncertainty of the outcomes of the projections of climate change that are to be worked out for the various sub-processes within the scope of the KLIWAS research programme.

3 Thematic Content of Research Task 2

As part of the KLIWAS research programme, Research Task 2 will, on the one hand, analyse changes that have already taken place in hydrological parameters in German coastal waters and estuaries on the basis of measured data; on the other, it will prepare projections based on numerical simulations of future changes in hydrological parameters that will probably occur as a

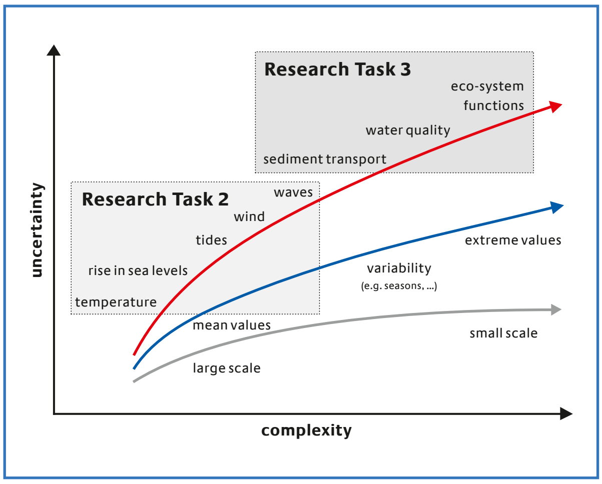

Fig. 1: Processes in coastal waters and estuaries – complexity and uncertainty (acc. to: PIANC EnviCom – Task Group 3 Climate Change and Navigation, 2008)

result of climatic change. Table 1 shows an overview of the projects in Research Task 2.

Consequences of climatic change that have already occurred will be analysed using existing measurement data of water levels, currents and sea swell in the North Sea and its estuaries. Among others, the results of Jensen & Mudersbach (2007) and Töppe (1994) on the development of water levels and those on sea swell development of the WASA group (1998) and Lamb & Weiss (1979) will be statistically analysed. The objective is to depict changes that have already occurred in the statistics of tidal key figures (tidal levels and currents) and sea swell, and to examine whether these show a trend towards an increase. Especially for the analysis of tidal water levels, a precise and absolute geo-reference value for tide gauge zero is required. This absolute geo-referencing will be worked out for the North Sea and its estuaries and other areas on the basis of results from the IKÜS (Integriertes Höhenüberwachungssystem in Küstenregionen – Integrated Coastal Monitoring System) project group (IKÜS-Projektgruppe 2008). Studies of the open sea will be concerned primarily with sea swell and trends in temperature and salinity.

The analysis of future climate-induced changes in the hydrological system, and the continuing analysis of changes that have already occurred, will be carried out with the help of numerical models. To do this, Research Task 2 draws on meteorological and oceanographic reference and scenario datasets that were prepared in KLIWAS Research Task 1 and to downscaled scenarios for coastal regions and estuaries regarding atmospheric and marine condition variables and circulation patterns for North Atlantic, North Sea and Baltic Sea regions. By comparing the results of the climate scenario models with the reference datasets, the possible climate-induced change of meteorological/climatological parameters and oceanographic/hydrographic parameters can be determined. The effects of expected climate scenarios on coastal regions and estuaries will be further localised in Research Task 2.

4 Objectives of the Projects in Research Task 2

The objective of Research Task 2 is to estimate the extent of the changes that have already taken place as a result of climate change and of those that can be expected due to an increase in the rate of climate change (IPCC 2007) in the hydrological system in coastal waters of the North Sea and the Baltic Sea and in their estuaries, and to define the uncertainties in the simulated impact of selected climate projections.

In order to reduce the uncertainties in the measurements derived from existing trends of rises in water level at German coastlines, quality-assured and geo-referenced water levels from different periods of time will be made available in a temporally and spatially homogeneous and globally compatible reference system. Tectonically and anthropogenically induced vertical movements will be recorded and taken into account here. With the help of depictions of water levels in a globally compatible reference system, classical gauge readings and results of satellite altimetry can be combined, so that conclusions can be drawn regarding variations in sea level in the oceans or at considerable distances from land.

Table 1: Projects in KLIWAS Research Task 2: Changes in the hydrological system of coastal waters

Proj. No. 2.01	Climate change scenarios for the maritime area and their parametrisation
Proj. No. 2. 02	Validation of climate projections for water level changes with regard to tectonic influences at the coast
Proj. No. 2. 03	Climate induced changes in tidal parameters and sea state statistics at the coast
Proj. No. 2.04	Vulnerability of hydraulic engineering systems at the North Sea and its estuaries due to climate change
ARGO	Array for Real-time Geostrophic Oceanography

On the basis of the quality-assured and georeferenced time series of water level readings, historic trends in the statistics of key figures for tides (Jensen et al. 2008a, 2008b), such as tidal high water (Thw), tidal range (Thb), tidal low water (Tnw), flood period (T_F) and ebb period (T_E) will be reanalysed. Besides the trends in the statistics of tidal key figures, statistics of flood current duration (T_f) and ebb current duration (T_e) and maximum and mean velocities of flood and ebb currents (v_f, v_e) as well as significant wave heights (H_s) and average wave periods (T_m) and their trends will be prepared using the measurements of current and sea swell carried out at the German coastlines.

Projections of expected changes in key figures for tides and sea swell, in current patterns and in other atmospheric parameters, such as temperature, barometric pressure, wind direction and speed, and oceanographic parameters, such as temperature, ice-formation and salinity will be determined for selected climate change scenarios by means of numerical simulations such as Grabemann & Weisse (2008). By using different model chains (so-called multi-model approach), an estimation can be made of the uncertainties of the projections.

The results obtained in Research Task 2 will form the basis for the investigation of the impact of climate change on the suspended matter content, quality and hydrological conditions and bank vegetation of coastal waters and estuaries in KLIWAS Research Task 3 (cf. Manz et al.). Research Task 2 thus forms the basis for the assessment of risk potential for the open sea and coastal areas and for the development of options for adaptation for the maintenance and future utilisation of marine waterways.

5 Summary / Looking to the Future

The results of the four projects in KLIWAS Research Task 2 supply specialist knowledge on the climate-induced changes that have already occurred, and those that can be expected in the future hydrological system of coastal waters and estuaries, thus forming the basis for the projects in Research Task 3. In Task 2, statements or projections will be prepared regarding meteorological parameters e.g. for wind, and oceanographic parameters, in particular, water level, current and sea swell.

By correcting the anthropogenic and tectonic influences on readings of tidal water levels, uncertainties in trends derived from the readings in, for instance, key figures for tides, can be reduced. In addition, measurements of current velocities and sea swell will be analysed for the first time from the perspective of a trend induced by climate change.

In regard to the projections of the expected meteorological and oceanographic conditions, uncertainties will be reduced by the use of a multi-model approach.

Through the depiction and evaluation of the uncertainties of the results of Research Task 2 in particular, the Federal Waterways Administration will be provided with the specialist foundational knowledge it requires to be able to participate pertinently and competently in the discussion with the interested general public, lobbyists and other decision-makers on issues surrounding the impact of climate change.

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Changes and Sensitivity of the Water Body State (Morphology, Quality, Ecology) and Adaptation Options for Navigation and Waterways – KLIWAS Research Task 3

Werner Manz (BfG), Hartmut Heinrich (BSH) & Harro Heyer (BAW)

1 Introduction

The projected climate change has the potential to affect various types of protected natural resources and to cause an increase in economic and health risks. A distinction must be made between direct effects, such as the more frequent occurrence of extreme weather conditions and the accompanying effects of storm tides, flooding and drought, and indirect effects. Indirect effects include risks which originate from climate-induced changes in ecosystems, living space or living conditions (Anonymous 2004; Persson et al. 2007; Working Group on Oceanic Hydrography 2008).

In the scope of the KLIWAS research programme, the higher federal authorities, the National Meteorological Service of Germany (DWD), German Federal Waterways Engineering and Research Institute (BAW), Federal Maritime and Hydrographic Agency (BSH) are working on nine projects dealing with issues of morphology, quality and ecology in the coastal and estuarine regions against a background of climate change, with the objective of being able to make reliable statements on the future usability of the functions of bodies of water. These economic and ecological functions of water (“ecological goods & services”, Meire et al. 2007) also include the use of the former as transport routes, reservoirs for drinking water, for angling, as recreational areas and for tourism. In the ecological sense, bodies of water fulfil important functions as a living space for flora and fauna and micro-organisms, as a genetic pool (keyword: biodiversity), in connection with natural purification of the environment and as a thermal and chemical climate puffer (carbon dioxide fixation).

Climate-induced changes in the quality of water conditions result in various areas of impact which must be examined in the light of the continuing development of legislative constraints (for example, economic management, Habitats Directive, German Environmental Damages Act, industrial safety, environmentally acceptable upgrading and maintenance of waterways) (NICHOLLS & KLEIN 2005; VON STORCH et al. 2007).

The benefit for society which can be expected from Research Task 3, besides the acquisition of knowledge in the form of quality-assured data, lies in an objectifiable, scientific assessment of the unavoidable haziness of the statements and a subsequent assessment of risks. In practical application, this leads to support in planning measures, for example, in the climate-related discussion of the current status regarding maintenance measures and to an increase in legal certainty, for example, in the evaluation of the environmental compatibility of materials for hydraulic engineering and in industrial and occupational safety. Through its political advisory services, KLIWAS fulfils a core task of government-funded research with the preparation of scientifically supported, reliable statements on issues of the impact of climate change.

2 Principles of Climate-induced Changes in Quality of the Condition of Bodies of Water

2.1 Estuaries and Coastlines

The structure and quality of waters in the coast and estuarine area is determined by physical, chemical and biological parameters, that is, by the type and volume of dissolved substances, temperature, bedload and sediment content as well as by the amphibian and terrestrial flora and fauna. These features may vary as a result of climatic changes. With regard to quality, a rise in temperature lowers the oxygen content of the water physically and biologically, as it boosts activities which consume oxygen and reduces the saturation limit of dissolved oxygen. Higher temperatures accelerate chemical weathering in soils, causing an increase in the input of organic and mineral sediments and of substances with a potential ecotoxicological effect into the water, especially in connection with intense precipitation. In turn, the quantity of surface runoff has a direct effect on substance concentration in the waters. Lower runoff can increase the peak concentration of certain substances, which function as nutrients, for example, nitrate. Higher temperatures and increasing input of nitrate boost the growth of algae (eutrophication effects), which in turn has consequences for the oxygen content of the waters (STRUYF et al. 2004; QUIEL et al. 2008). Following a rise of average water temperatures and the associated reduction of the oxygen content, microorganisms which affect health may occur in greater concentrations; increased occurrence of algal bloom resulting in the formation of algal toxins is another possible scenario (MASO & GARCES 2006). With rising temperatures, an increase in the mobility of organic pollutants can generally be expected (MA et al. 2004). As a result of intensified diffusion, the pollutants fixated in aquatic and marine sediments are remobilised, which, overall, can lead to an increase in the input of pollutants in sediments.

From the point of view of quantity, the suspended matter content in estuaries depends on various hydrological and meteorological factors. It can be expected that as a result of increasing water depths caused by the rise in sea level, and an increase in extreme weather situations, which are connected with greater frequency of occurrence and more intensive high water situations, as well as more frequent and longer-lasting low water periods, the suspended matter content and, therefore also the demands on sediment management strategies in the estuaries, will undergo long-term change (KAPPENBERG & FANGER 2007; BFG 2008). On the one hand, the volume of sediment that has to be moved, the characteristic sediment transport conveyor belts in the coastal foreland and estuaries, and the main sedimentation locations and sedimentation volumes will change, while on the other, pollutant concentration and quantities may vary. Both the change in quantity of sediment transportation and a change in the quality of their content structure with regard to pollutant load call for the development of options for adaptation for long-term strategies for the management of bodies of water. As a result of climate change, it can also be expected that the stress on hydraulic construction materials used for the construction and upgrading of federal waterways will increase and change in terms of quality, which will necessitate rethinking on environment-compatible hydraulic construction materials (Müller et al. 2007).

From an ecological point of view, the immigration of new plant species as a result of climate-induced changes could cause undesirable modifications in the bank vegetation (Pompe et al. 2009) and impair the protective function of plant communities.

2.2 Marine Waters

Whereas structure plays a major role in estuaries and coastal waters, in regard to the open sea, the focus of attention must be on the atmosphere and water bodies, and their physical changes in the course of a change in climate. The weather events of the winter 2006/2007, in which the physical condition variables lay above the hitherto known range of fluctuation are already being seen as the harbingers of conditions that we may have to reckon with. On 1st November 2006, the estuary of the River Ems experienced the highest storm tide in 100 years. Only because the wind direction changed not long before high tide, was the North Frisian coast spared an exceedingly severe storm tide. Unusually high temperatures of atmosphere and sea, as well as the highest wave observed to date in the North Sea (presumably higher than 18 metres) are understood as an indication of coming changes. The high temperatures of the water in the Baltic Sea in winter have created conditions favouring the immigration of species which, it is suspected, are capable of causing economic damage to the fishing industry. The extreme build-up of heat in summer means that the North Sea no longer cools to below the long-term mean value, even during the colder winters. This means that not only in the oceans, but also in German coastal waters, climatic change can lead to hitherto unknown risks for navigation and the use of oceans. Consequently, it is of vast importance that we know the extent to which the condition variables of atmosphere and water bodies may diverge from previous conditions as a result of climatic change.

3 Thematic Content of Research Task 3

3.1 Estuaries and Coastlines

In order to secure navigation channel depths, extensive maintenance dredging work must be undertaken in the North Sea estuaries of the rivers Elbe, Weser and Ems. The spatial and temporal occurrence of shallow depths which impede navigation depends to a very large extent on hydrological and meteorological factors and on the geometry of the waterway. The possible effects of climate change on the suspended matter content in the estuaries must be recorded and analysed quantitatively in order to be able to adapt sediment management to the new conditions and to develop at a sufficiently early stage adaptation strategies that will only become effective in the long term for reducing the volume of wet dredging.

Ecologically alarming situations of low oxygen content occur in the estuaries of the Elbe and the Ems. In the summer half-year, periods with low discharge contribute to low oxygen content, when the water remains (in the estuary) for a long period, and water temperatures are high. In the Ems estuary, the concentrations of suspended matter, which have risen dramatically in connecting with upgrading, are responsible for the very critical oxygen situation in the Lower Ems which occurs in the summer when water temperatures are high. Future climate-induced clusters and the increase in intensity of hydrological and meteorological extreme events, such as long low-water periods with high air temperatures, may lead to an aggravation of the oxygen situation in the estuaries. Furthermore, rising water temperatures and, at the same time, longer periods in which the water remains in certain sections of the estuary will lead to an intensification of the breakdown processes, so that a higher microbial consumption of oxygen may occur, particularly in the summer. For this reason, the effects of possible climate-induced changes

Table 1: Projects KLIWAS Research Task 3: Changes and sensitivity of the water body state (morphology, quality, ecology) and adaptation options for navigation and waterways

Proj. No. 3.01	Impacts of climate change on navigation and other uses of the sea
Proj. No. 3.02	Adaptation options for waterways and ports at the German coast and coastal protection in extreme weather events
Proj. No. 3.03	Impacts of climate change on the budget of suspended particulate matters in North Sea estuaries
Proj. No. 3.04	Impacts of climate change on microbial water quality and their implications for dredged material management in coastal waters
Proj. No. 3.05	Impacts of climate change on stability and environmental relevance of hydraulic engineering materials in coastal waters
Proj. No. 3.06	Impacts of climate change on the transport behaviour of contaminated sediments and maintenance of coastal waterways
Proj. No. 3.07	Impacts of climate change on patterns of organic pollutants in coastal waters
Proj. No. 3.08	Climate change related impacts on the oxygen budget of North Sea estuaries due to alterations of river discharge and nutrient and carbon load - Potential adaptation strategies for navigation and sediment management
Proj. No. 3.09	Vegetation shift in German estuaries due to climate change and consequences for bank protection and maintenance

in the oxygen content in the estuaries must be recorded and quantified so that the utilisation of the estuaries can be guaranteed in the long-term, even under the altered conditions.

From the perspective of quality, an increase in intensity and frequency of high water events can also be expected to lead to additional input of pollutant-laden solid matter from the inland areas into the coastal regions of the North Sea and the Baltic Sea. The increase in high water and storm events can lead to intensified re-suspension and, thus, to remobilisation of pollutant-laden old sediments from existing dump points and ancillary areas of the bodies of water and, thereby, to climate-induced changes in organic pollutant patterns in the sediments with the associated consequences for the maintenance of coastal waterways in terms of suspended matter and water pollution. Both aspects may contribute to an increase in the pollutant load of the sediments that must be dredged at the present time. Especially in the inner coastal waters of the Baltic Sea, eutrophication effects may occur in greater intensity, as the shorelines areas, which are often used for agriculture, will be submerged more frequently. During storm tides, prolonged low water phases and, in the event of a rise in sea level, an increase in upstream transport of marine sediments with a lower pollutant load can be expected which, when associated with a parallel increase in the solid matter volumes, can lead to a reduction of the pollutant concentration in dredged material by causing a dilution effect.

The long-term safety of structures and bank protection measures depends on the durability of the hydraulic construction materials that are used, the stability and environmental compatibility of which are, in turn, dependent on water temperature, water chemistry parameters and hydrological load. As a result of increasing frequency of extreme hydrological events, the alternation of dry and wet conditions at bank protection measures and, thus, of the physical and bio-chemical assault (oxidation and corrosion) on hydraulic construction materials will increase. Until now there has been no quantification of mean and long-term effects on hydraulic construction materials, nor has any estimation been made of the impact of hydraulic construction materials on their surroundings (water, sediments, suspended matter and biota) in order to be able to implement suitable adaptation strategies.

From the perspective of landscape management and animal ecology, climate change will possibly influence the structure and species composition of the vegetation cover along coastlines and estuaries. The expected rise in temperatures will modify breakdown processes in marshy soils and, consequently, their function as a filter. Due to the assumed increase in the frequency of extreme hydrological events, an increase in the dynamics of shore and flood plain vegetation can be expected. Especially, change in both quantity and quality can be expected in the common reed-stands which are so important for flood plain protection. Common reeds may be lost or impaired in their function as a form of bank protection through narrowing or fragmentation of the reed belt. At the disturbed locations, invasive species may become established. These often have a weaker root system than common reeds. It can therefore be expected that the flood plain and its structures will be subject to a greater risk of erosion. Protective measures for shores and dykes will then be required in large measure.

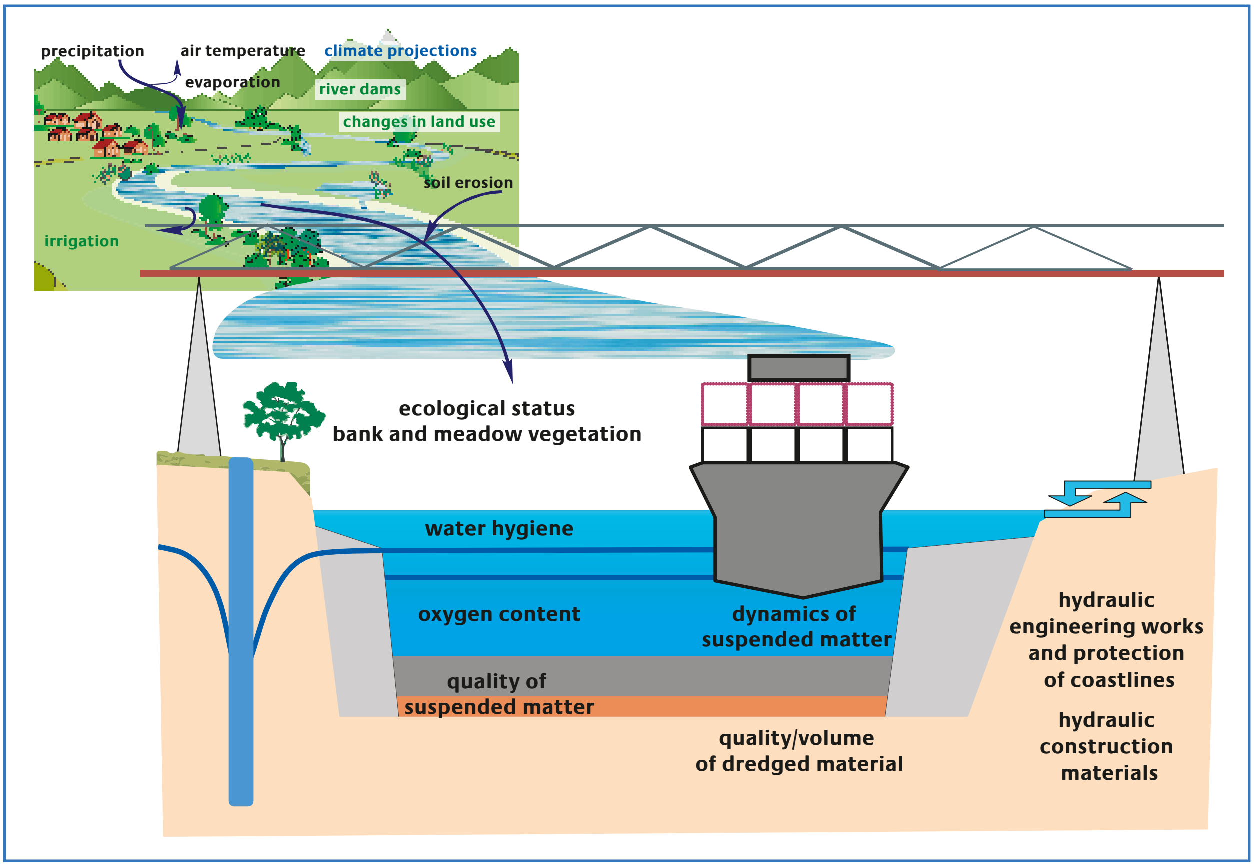

Fig. 1: Themes and processes within the overall system “bodies of water” which will be dealt with in the course of KLIWAS Research Task 3

As a consequence of the expected rise in average water temperatures and the associated reduction of oxygen content, health-relevant micro-organisms will in future occur in higher concentrations in coastal areas than previously (for instance, *Vibrio vulnificus,* faecal-coliform bacteria) or blue-green algae will produce toxins (algal toxins). The increase in bacteria which can cause infections also increases the health risk from contact with water or sediments during leisure activities or through working in or near bodies of water.

3.2 Marine Waters

Reactions to weather situations are already “everyday business” in marine navigation, use of oceans and coastal protection. Forecasting services for wind, sea swell, current and water level conditions, especially, permit a fast reaction to immediate threats, thus preventing damage to people and materials. Long-term records indicate how extreme weather and oceanic situations may behave and permit foresighted planning of naval architecture, routes, construction design and coastal protection measures. So-called climatologies, which statistically describe the scope of risk, form the specialist basis.

The effects of climate change have a less significant effect on immediate events; on the contrary, they primarily affect longer term planning. On a global scale, it may be possible to open new routes (keyword: North East Passage or Northern Sea Route). On a regional scale we must be prepared for impact mainly through changes in the atmospheric and oceanographic circulation patterns and in the dynamic intensity (sea swell, waves, currents) and also with an impact on the ecosystem through the use of oceans. In Research Task 3, the eventual consequences for as many sectors of oceanic use as possible, with specific reference to the open sea, should be estimated on the basis of the results of Research Task 2.

4 Objectives of the Projects in Research Task 3

4.1 Estuaries and Coastlines

The changes of atmospheric and climatological conditions determined with the help of reliable climate scenarios will be investigated using numerical modelling with regard to their oceanographic impact (Grabemann & Weisse 2008) and their regional and local consequences for marine navigation and use of seaports, use of the oceans and the environment (Grossmann et al. 2007). The objectives are the identification of specific risk potential, the timely introduction of adaptation measures and the prevention of ecological and economic damage. The quantitative studies extend primarily over the North Sea and the adjoining North Atlantic, since the latter strongly influences conditions in the North Sea. Selected model chains will also include the Baltic Sea.

In view of possible influences on the ecological condition, scenarios will be developed regarding the impact of physical changes on marine and coastal ecosystems and their consequences. For the North Sea estuaries of the Elbe, Weser and Ems rivers, the available data on suspended matter covering a long period of time will be evaluated and statistically analysed with a high temporal resolution in order to identify and quantify the relevant climatic and hydrological influencing factors on the types of utilisation.

The further development and application of the water quality model “QSim” (Kirchesch & Schöl 1999; Fischer et al. 2007) will answer specific questions on the consequences of climate change for the oxygen content of the North Sea estuaries. In the course of the project, the effects of a change in the input of matter from the middle reaches into the upper regions of the estuaries will first of all be analysed and estimated in a system study using the one-dimensional model “QSim” for the German estuaries. For water quality modelling for the whole estuary, the simultaneous development of a two-dimensional version of the quality model (“Tide-QSim”) is necessary, with which, subsequently, the impact of the climate-induced changes can be projected onto the entire estuarine oxygen content by means of modelling of various scenarios.

From the point of view of quality, the interdependencies of the temporal and spatial changes of the pollutant concentrations in solid matter of the North Sea coast, the changes in the input of pollutants from inland regions into coastal waters and the changes in sedimentation and erosion features will be investigated against a background of changing hydrological and meteorological constraints. The expected reduction of pollutant load as a result of increased upstream transport of less pollutant-laden marine solid matter into the North Sea estuaries will also be examined. In the Baltic Sea region, the climate-induced changes in this input or in the remobilisation of nutrients and the accompanying eutrophication effects will be examined. On the basis of these results, the influence of climate change on the content of pollutants and nutrients and on the pollutant content fixated in the sediments in the estuaries of the rivers Elbe, Weser and Ems and in the Baltic Sea coastal region will be estimated.

The results of the studies on heavy metals and other typical pollutants for this field in suspended matter and sediments will be analysed in view of their suitability as tracers for climate-induced change in the transport of finely grained cohesive solid matter in the North Sea estuaries.

The ecological question will be dealt with using the example of the tidally influenced estuaries of the Weser and the Elbe rivers, as in both of these, nearly-natural bank vegetation is still present on a large scale. A comparison of the two river systems regarding the spread of highly competitive neophytes species is important, as immigrant species have already become established in the Weser estuary, whereas the boundaries of the area of spread for these species run through the estuary of the Elbe.

The studies on the influence of climate-induced factors on hydraulic construction materials cover the coastal systems of the North Sea and the Baltic Sea. Here, sections of waters with specific hydraulic construction materials, which can be classified as typical in terms of their water structure will be selected as representative areas for study. In sum, the requirements for hydraulic construction materials for coastal waters that are to be expected as a result of the projected climate change will be estimated, and statements made about the types of material that will permit long-term and environmentally compatible operation of coastal protection systems.

4.2 Marine Waters

Task 3 will focus on developing principles for specific adaptation options for the support of all kinds of use of the oceans, particularly for navigation, wind energy, food production, and also on the impact on tourism. An essential factor will be the likelihood of occurrence of extreme events which have a major impact on navigation (risk of average) and wind farms (structures suffer acute or chronic damage or stress). In this context, the prediction of this type of event should be facilitated, so that the services of the BSH and the DWD in this field can be improved.

It is also expected that indications for the improvement of projections of temperature and salinity will be acquired. This is important both for navigation (ice

Fig. 2: Results of wave action on the FINO research platform near Borkum

drift) and for the ecology of the oceans (changed ranges of species in both commercial and non-commercial species).

A responsible projection cannot be made on the basis of numerical models alone. Models must be tested and validated with measured data. Measured data covering both the area and long periods of time will be required for checking the accuracy of projected conditions in the oceans. This task will therefore also examine whether the monitoring of the relevant physical determinants of the oceans is able to satisfy the standards required.

5 Summary / Looking to the Future

In its function as the proprietor of the federal waterways, the Federal Republic of Germany, in the current interpretation of the law, is responsible not only for ensuring uninterrupted and safe navigation, but also for the quality situation of the waters (keyword: ecological condition). As the impact of climate change on the federal waterways is not limited only to aspects of quantity, the projects of Research Task 3 will also deal with issues that are of importance for the long-term utilisation of the waterways with regard to both economic and ecological aspects.

The results of the projects will be provide the foundational specialist knowledge required to be able to participate pertinently and competently in the discussion with the interested general public, lobbyists and other decision-makers on issues surrounding the impact of climate change.

These individual issues concern matters such as climate-induced physical effects on waterways, navigation, coastal protection and hydraulic construction materials (projects 3.01, 3.02 und 3.05), volume and quality of suspended matter and sediments (projects 3.03 und 3.06), their material composition (project 3.07) and their ecological impact on the estuaries and coastal waters in view of the signs of climatic change (projects 3.04, 3.08 and 3.09).

The resulting products will be specific options for adaptation for the individual sub-areas which will enable the decision-makers to adequately meet the challenges arising from climate change while continuing to operate the waterways economically and safely, while still retaining the diversity of their functions for utilisation and their ecological quality.

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Changes in the Hydrological System: Sediment Budgets, Morphology and Adaptation Options for Inland Waterways and Navigation – KLIWAS Research Task 4

Thomas Maurer (BfG), Hans Moser (BfG) & Andreas Schmidt (BAW)

1 Introduction

It is feared that one consequence of climate change will be an increase in the frequency and duration of extreme discharge conditions in German rivers. This would have an especially large impact on the free-flowing inland waterways and on navigation. In order to obtain a reliable basis for political decisions on a strategy for action, an estimation of the possible consequences must first be made.

2 Climate Change and Impact on Waterways and Navigation – the Specialist Background

The usability of inland waterways depends on the water levels and the morphology of the riverbed. These are ultimately determined by the meteorological and hydrological situation in the river catchment area which could change through the influence of the projected climate change. Atmospheric processes, such as precipitation and evaporation and the terrestrial parameters, that is, the cross section of the rivers, their gradient, land use, soil properties and the water retention capacity of the landscape influence conditions. In the transition zone at the coast there are additional factors in the form of tidal water levels which cause backwater and areas of brackish water.

2.1 Discharge

The water supply and its seasonal distribution determine the depths of water that can be used by shipping and, thus, also the capacity of the individual waterways. From that point of view, runoff, and any possible change in discharge, is a central parameter which must be anticipated (mean value, variability and extremes). The climate projections indicate changes in the frequency and intensity of extreme weather periods and phenomena. Through the expected warming, we must furthermore reckon with the possibility of a smaller volume of water being stored in the snow cover, for example, in the Alpine region and in the higher regions of the lower mountain ranges (such as the Central German Uplands). The role of the latter as a buffer would thus decline, and the runoff regime would change accordingly. The result would be higher volumes of discharge in the winter and lower summer discharge. Individual measurement series for the River Rhine already indicate that the month with the lowest discharge, which is relevant for navigation, is moving forward in the course of the year. Examples showing that this tendency may continue in future can already be found in individual calculations of model chains. However, these examples have not yet been corroborated. Ultimately, changes in regime of this kind could also lead to more frequent, unfavourable overlapping of extreme runoff situations from different parts of large catchment areas, leading to the occurrence both of longer low water periods and more extreme high water events.

2.2 Sediment Balance and Waterway Bed

Besides runoff, the sediment balance and the condition of the bed of the waterway are also critical for navigation. Large scale spatial and temporal changes affect the channel depth and the maintenance effort required to keep the channel free. Tendencies to sedimentation and negative large scale or long-term developments in a river bed call for active sediment management. Knowledge of developments in bedload and suspended matter content is of special importance here. If the morphological conditions in inland waterways change as a result of climate change, the question must be answered as to how management of the waterways by the Federal Waterways and Shipping Administration (WSV) should be adapted in order to stabilise the depth ratios of the federal waterways. This first requires a substantiated estimation of the actual extent of impact on the transport system shipping/waterways.

2.3 Extent of Impact

The impact of changes in discharge and sediment transport would be complex. Besides inland navigation, it would affect even the many related areas, above all industries which depend on low cost transport of bulk goods, but also port operators and the warehousing and logistics business and, finally, the German Federal Waterways and Shipping Administration (WSV) which is responsible for the operation, maintenance and upgrading of federal waterways. Changes in the conditions of navigation channels which, because of the reduction in the maximum loading draught, would have a major effect on transport costs could impair the low cost and reliability of waterways-related transport and, thus, have a detrimental affect on the competitiveness of industrial sectors with a high affinity for bulk goods and also on the reliability and safety of this mode of transport.

2.4 National and International Cooperation

The higher authorities of the BMVBS are very well networked for the study of these problems. At a national level, there is close cooperation with the federal states and other government departments in regard to agreement on the derivation of consistent climate projections for the area of the Federal Republic of Germany. There is also wide international cooperation, above all with neighbouring states who share the large river catchment areas with Germany. For example, climate change scenarios for the Rhine basin have been and are being prepared in working groups from Switzerland and the Netherlands; these countries also use different model approaches for hydrological modelling. The Federal Institute of Hydrology (BfG) plays an active part as a coordinator for these activities in the corresponding working groups of the KHR (Commission for the Hydrology of the Rhine Basin – CHR) and the IKSR (International Commission for the Protection of the Rhine – ICPR). In addition, good relationships are maintained with the CCNR (Central Commission for Navigation of the Rhine).

The BfG has cooperation agreements with the colleagues at the Dutch Water Service (Rijkswaterstaat) and the research foundation DELTARES and the cooperation regarding the Rhine Basin, which has already been pursued for many years, will be continued in this context. A similar cooperation is currently being developed with the Czech colleagues at the CHMI. In the scope of Research Task 4, close cooperation with Czech scientists and government departments is planned in order to tackle the climate problem in regard to the Elbe river basin.

The BfG is also a regular participant in projects/project proposals of the EU research and development programmes – currently, for instance, in the Seventh Framework Programme (FP 7) Cooperation Work Programme: Transport Effects of Climate Change on Inland Waterway and Transport Networks (Proposal ECCONET). Another network link exists through the development structures projects (EU INTERREG programme). For example, with the participation of the BfG, climate projections and options for adaptation will be agreed with the states with territory covering the Alps in the scope of the project INTERREG IVB "Alpine Space" project AdaptAlp (a logical continuation of the INTERREG-IIIB project ClimChAlp).

Finally, the BfG is making a significant contribution to the international research programmes that are concerned with the monitoring and modelling of global climate change by operating the global database for runoff (Global Runoff Data Centre, GRDC) under the patronage of the World Meteorological Organization (WMO). In this context, many contacts and a lively exchange of ideas with international researchers have developed. The results of these research programmes support the continuous improvement of the important, coupled climate and ocean models required for regional climate modelling.

3 Challenges for the Management of Federal Waterways

3.1 Task of the German Federal Waterways and Shipping Administration (WSV)

Inland navigation requires reliable conditions which guarantee safe, easy and, at the same time, economical operation. The navigation channels must have stable courses with adequate depth and width and moderate flow velocities. To ensure the best possible utilisation of this transport mode under variable natural conditions, a comprehensive management strategy – at considerable expense – must be undertaken by the German Federal Waterways and Shipping Administration (WSV). This includes:

- operation (regulation of traffic, access to information systems, equipping with navigation signals, provision of landing stages or ports)
- maintenance (maintenance of the condition of hydraulic engineering structures and materials and of the navigation channel in line with planning approval)
- upgrading of federal waterways (changes requiring planning approval for capacity adjustment or improvements in traffic safety and erosion protection).

3.2 Competing Uses of Federal Waterways

Federal waterways form a part of river basins which are utilised for many, and sometimes competing purposes; the function as a federal waterway is only one of these. The use of naturally flowing waters for transport purposes, for provision of water supplies for households, industry and trade, irrigation for agricultural requirements, waste water disposal, the generation of energy, risk-free transport of flood water and ice, fishing industry and leisure and recreation is associated in each case with certain demands. In order to fulfil these demands the various system parameters will require differing optimisation strategies.

3.3 Necessary Reconciliation of Sectoral Interests

Most of the utilisation interests mentioned above are subject to legislative measures, and the areas of responsibility are generally covered at different administrative levels (municipalities, federal states, (German) federal government, neighbouring countries). As a general rule, changes in existing uses are managed by means of planning approval procedures which, in the context of legal regulations and directions (e.g. WFD, HD, FD, Water Management Act, Water Acts of the Federal States, VV1401 (administrative ruling 1401), ERA, EIS, SEA, work safety regulations, HABAB, HABAK, ...) ensure that the different sectoral interests can be reconciled.

3.4 Necessity for Comprehensive Analysis

The possible impact of climate change will affect all the users mentioned. Any kind of adaptation measures in one field may interfere with the existing "balance of use", which may then require comprehensive trans-sectoral re-assessment and, possibly, planning approval of the situations along the federal waterways. The topic adaptation of the federal waterways to climate change must therefore be dealt with on an objective and scientific level. As the owner of the federal waterways, the Federal Government must concentrate not only on the immediate core tasks of maintaining safety and ease of shipping traffic but, in a supportive role, also deal with the impact on other utilisation interests. With its higher federal authorities, the DWD, BfG, BSH, and BAW, the BMVBS has at its disposal its own wide-ranging, departmental expertise in the relevant fields of meteorology, hydrology, hydraulic engineering, morphology, water quality, ecology, construction technology and navigation, all of which benefit the KLIWAS research programme.

3.5 Statement of the Problem

In Research Task 4, which we are describing here, the following problems will be addressed:

- inadequate knowledge of the impact of climate change on runoff/discharge patterns, sediment transport and channel morphology, and thus, also lack of knowledge of the range of possible future critical hydraulic/morphological conditions in comparison to the present day

- inadequate knowledge of the susceptibility of the affected sectors (above all, inland navigation, industry and the WSV, as the body responsible for the operation, maintenance and upgrading) with regard to changed hydraulic/morphological conditions
- inadequate knowledge of the options and costs for investment-related or operative courses of action, such as hydraulic engineering and water management measures, the introduction of innovative navigational guidance systems, adaptations of the fleet structure, change of traffic carrier etc.

A solution to these problems is essential for the formulation and parameterisation of benefit-cost analyses for business and political economics which will then serve as the basis for the political decision for an adaptation strategy. The objectives for Research Task 4 are derived from these considerations.

4 Objectives of the Projects in Research Task 4

The objective of projects 4.01 and 4.02 is to develop a method for deriving a family of scenarios for climate variables (especially precipitation and weather situation classes), discharge (especially low water), sediment transport rates and river bed development up to the year 2100 under the impact of climate change and to apply this to the rivers Rhine, Elbe and Danube. In order to understand the uncertainty of these scenarios, numerous model chains will be simulated, that is, combinations of three emissions scenarios, five global and seven regional climate models and two hydrological models and one hydro-morphological model. The results will be used to derive statistical key figures for the historic and future time periods and these figures will summarise average and extreme characteristics of the scenarios in differing spatial and temporal assessments. The suitability of the model can be evaluated by making a comparison to the relevant key figures from the measured data from the historic period. The comparison of the model data of the historic period to that for the future periods of time will provide the climate change indicator in the form of a range and a distribution function of the interesting parameters, above all extreme low and high water events and the associated changes in sediment transport and the riverbed.

The objective of project 4.01 is, furthermore, to study the susceptibility of inland navigation and the forwarding industry to changes in the discharge regime, using the example of the River Rhine; the cost structures for various types of vessel and load depending on transport relations and water levels will be determined and parameters ascertained by means of company surveys and the analysis of transport statistics, which will form a basis for the parameterisation of benefit cost analyses for business and political economics.

A further objective in Research Task 4 is to work out courses of action regarding investment and courses of

Table 1: Projects of KLIWAS Research Task 4: Changes in the hydrological system: sediment budgets, morphology and adaptation options for inland waterways and navigation

Proj. No. 4.01	Impacts of climate change on hydrology and management options for the economy and inland navigation
Proj. No. 4.02	Climate projections for sediment budgeting and river morphology
Proj. No. 4.03	Options for the regulation and adaptation of hydraulic engineering measures to climate induced changes of the discharge regime
Proj. No. 4.04	Minimum width of fairways for safe and easy navigation
Proj. No. 4.05	Process studies on the development of ice formation in waterways

action to limit the feared negative impact of climate change on inland navigation. The expansion of the nautically usable "water level window" is of primary importance. This means primarily that depth ratios in the navigation channel at low water will be expanded in comparison with the current status, so that the transport chain is not interrupted.

From the point of view of hydraulic engineering, several measures for adaptation to climate change will be investigated in the projects 4.03 and 4.04. Project 4.04 will determine minimum channel widths using multidimensional investigations of navigational dynamics in selected sections of the Rhine in which there are relevant navigational bottlenecks. These studies will take account of the fact that there is a smaller requirement for traffic space for shipping at low water, as smaller vessels are used more frequently and because flow velocities are reduced. Furthermore, anticipated technical enhancements to the Rhine fleet in the future, in regard to improved rudder action or new information systems, will also be taken into account. The optimisation of the existing navigation channels will be considered as well as the behaviour of a deeper "channel within the channel" to provide greater depth during low water conditions, for instance, through bedload management measures.

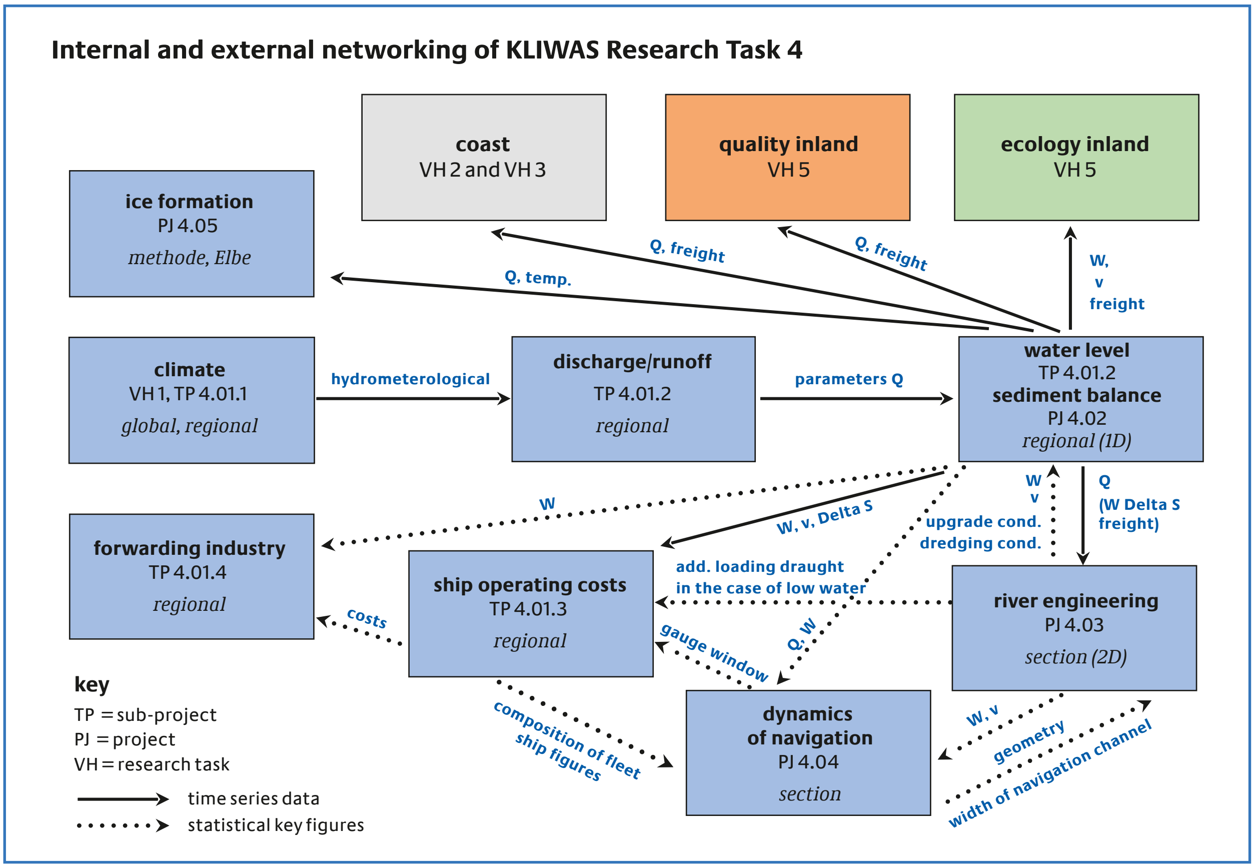

Fig. 1: Internal and external networking of the projects and sub-projects of Research Task 4 and the other tasks

In Project 4.03, the options for implementation of width restrictions of the navigation channel by various engineering and technical measures will be studied along sample stretches. These range from an improved dredging strategy through moveable groynes to temporary damming measures. They are based on multi-dimensional hydraulic and morphological models which are calibrated not only at the current status, but also at a selected measure which will be implemented in the course of the task and tested for its effect. In the results, the measures will be assessed in terms of their constructional and operational feasibility and their benefit in relation to cost.

Finally, the objective of project 4.05 is to carry out process studies on the trends in ice formation in waterways and, in this context, to integrate a module for the modelling of ice formation on free-flowing inland waterways into the standard hydraulics software SOBEK.

Figure 1 summarises the internal and external networking of the projects and sub-projects within Research Task 4 and with the other tasks of the research programme. In particular, it shows the data flows between the sub-projects. It can be established that, strictly speaking, it would be necessary to exchange data between many projects and sub-projects iteratively. However, for technical working reasons, this can in some cases not be carried out at all, or only with simple iteration, as the numerical processes required would be too complicated.

5 Summary / Looking to the Future

It is feared that one consequence of climate change will be an increase in the frequency and duration of extreme discharge conditions in German rivers. This would have an especially large impact on the free-flowing inland waterways and on navigation on these waterways. The assessment of the possible impact requires three steps:

1. Development of scenarios for future trends in the sediment transport and channel morphology, for the evaluation of the range of possible future critical hydraulic/morphological conditions compared to those of the present day
2. Ascertaining the susceptibility of the affected sectors (above all, inland navigation, industry and the WSV, in its role as the body responsible for the operation, maintenance and upgrading) with regard to changed hydraulic/morphological conditions
3. Preparation and analysis of possible investment-related or operative courses of action, such as hydraulic engineering and water management measures, the introduction of innovative navigational guidance systems, adaptation of the fleet structure, change of traffic carrier etc.

For this, methods for the hydrological/hydromorphological system in the field of inland navigation will be developed in Research Task 4 and implemented using the example of the rivers Rhine, Elbe and Danube. The results of this task form the basis for a subsequent, necessary benefit-cost calculation in terms of political economics from which a strategy for action can then be derived by the political decision-makers.

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Impacts of Climate Change on Structure, Ecological Integrity and Management of Inland Waterways – KLIWAS Research Task 5

Helmut Fischer (BfG)

1 Introduction

The structure and ecological condition of inland waterways are determined by chemical, physical and biological parameters, that is, by the type and volume of dissolved substances, by temperature, bedload and sediment structure as well as by the flora and fauna of the water, the sediments, the riparian zone and the flood-plain. These factors influence each other and are governed in differing ways by changes in hydraulic engineering measures and by climatic changes.

The diverse features and functions of an ecosystem (for instance, in the balance of matter and for biodiversity) can be summarised with the term “ecological integrity”. Consequences of climate change on the ecological integrity of flowing waters are described briefly in the IPCC report (Working Group 2, Fischlin et al. 2007) and in the report of the European Environment Agency (EEA 2008). Some of these consequences are evident in the processes of physical, chemical and biological interaction in the bodies of water and have recently been the subject of investigation of many recent projects and initiatives (e.g. EU project: Euro-limpacs, DFG Priority Programme AQUASHIFT). Usually the direct impact of change in one parameter, such as temperature, on specific target parameters, such as fauna, is examined. This reveals the complexity of the relationships, as one cause often affects more than one component in a system, and the effects produced are frequently coupled with each other and non-linear. Climate change has a multifactorial effect and its impact on waterways is, at the same time, influenced, or possibly even hidden, by additional anthropogenic and natural stress factors. This necessitates further detailed model examination of the underlying processes.

In this contribution, the possible effects of climate change on the ecological integrity of navigable rivers will be described and placed in the context of the consequences for management of inland waterways. This defines the research requirement which is to be covered by the projects that form Research Task 5.

2 Impact of Climate Change on the Ecological Condition of the Inland Waterways

A rise in temperature lowers the oxygen content of the water physically and biologically, as it boosts activities which consume oxygen and reduces the saturation limit of dissolved oxygen (FISCHLIN et al. 2007). Furthermore, higher temperatures and increased radiation intensify temperature stratification in bodies of water. In waterways that are regulated by damming or are interrupted by lakes (e.g. the rivers Saar, Neckar or Havel) stratification events may then occur more frequently and prevent thorough mixing, which exacerbates the existing lack of oxygen (BECKER et al. 2009).

Higher temperatures will probably also lead to increased use of biocides both in the commercial and private sectors. Higher input volumes of these substances from point and non-point sources would then be expected in the river catchment areas. Particularly in relation to intense precipitation and considering that, for example, the break-down metabolism in soils will change as a result of higher temperatures, the loads of organic and mineral sediments along with substances with a potentially ecotoxicological effect could lead to problems in the waterways (FISCHLIN et al. 2007, SMITH et al. 2007).

The quantity of surface runoff directly affects the substance concentration of dissolved material (WHITEHEAD et al. 2009). Lower runoff can increase the concentration of certain chemical components, for example, nitrate, in bodies of water. Peak concentrations will then occur following intense precipitation (WHITEHEAD et al. 2009). Higher temperatures and rising nutrient inputs increase the growth of algae (eutrophication), which, in turn, has consequences for the oxygen content of the waters (WETZEL 2001). The system is regulated by the natural predators of the algae ('grazers'), and climate change may cause reactions both of reinforcement (damage to grazers) and mitigation (favouring grazers).

As a consequence of the expected rise in average water temperatures and the associated fluctuation/reduction of oxygen content, health-relevant microorganisms (for instance, faecal-coliform bacteria) may in future occur in higher concentrations (GREER et al. 2008); algal blooms and the formation of algal toxins may occur more frequently and in greater intensity. Because of the possible increasing dominance of blue-green algae in some waterways and their immediate toxic effect, an increase in contamination of the sediments through algal toxins may occur. Regarding organic pollutants, an increase in their mobility can generally be expected as temperatures rise. As a result of intensified diffusion, pollutants adsorbed to aquatic sediments are remobilised, which overall can lead to an increased input of pollutants into the sediments.

The fauna of inland waterways is affected directly (temperature, discharge) and indirectly (oxygen content, sediment structure and toxicology) by climate change (e.g. ALLAN et al. 2005, KOOP et al. 2007). Temperature affects metabolism and can lead to the exclusion of certain species, but also to circumstances favouring other species. If key species, such as bivalve mussels are affected, this will have immediate consequences on the development of algae and on oxygen concentration.

The composition of species in plant communities will above all be modified as a result of changes in hydrological conditions (ground and surface water levels and their fluctuations). Changed behaviour of sedimentation and erosion processes in rivers will also affect the vegetation of riparian meadows, as these react to the new conditions at the location (MORAN et al. 2008, ROOD et al. 2008).

The suspended matter content in waterways depends on various hydrological and meteorological factors. It can be expected that due to a possible increase in extreme weather situations which are related to more frequent and more severe heavy precipitation events, and more frequent and longer lasting low water periods, the suspended matter content and sediment balance will undergo permanent change. In this way, the greater frequency of high water events can lead to increased suspended matter, while changes in runoff conditions overall can alter the concentration and volume of particle-bound pollutants.

3 Statement of the Problem for the Management of Waterways

Not only organisms and natural processes in bodies of water may be affected as a result of climate change, but also the ecological system services used by people. Preservation of these services, while taking into consideration, and in some cases, improving, ecological integrity is one of the goals for the management of federal waterways. In order to develop the best possible management strategies, the influence of climate change on waterways and their vulnerability must first be described (Fig. 1).

To guarantee navigation channel depths, extensive dredging works are being carried out in free-flowing stretches of the rivers Elbe and Rhine, and also at locks and in reaches between barrages. The spatial and temporal occurrence of shallow depths which impede navigation depends, just as sedimentation in still water zones (such as groyne fields), to a very large extent on hydrological and meteorological factors and on the geometry of the waterway. The possible effects of climate change on sediment transport and suspended matter content in inland waterways must therefore be recorded and analysed quantitatively in order to be able to adapt sediment management to the new conditions and to develop effective strategies for adaptation which will already allow for the change in sediment volume in advance by setting in place the appropriate measures.

Higher temperatures and a change in the runoff regime will presumably lead to additional input of pollutant-laden solid matter from the catchment area and to changes in the pollutant pattern. An increase in high water and storm events can lead to intensified re-suspension and, thus, to remobilisation of pollutant-laden old sediments from ancillary areas of the navigation channels, especially from groyne fields (BÖHME et al. 2005), and, thereby, to climate-induced changes in organic pollutant patterns in dredged material with the associated consequences for maintenance in regard to suspended matter and water pollution. Both aspects may contribute to an increase in pollutant load of the sediments that must be dredged at the present time and, thus, have a direct influence on future dredging management.

Increased eutrophication effects may occur both in regulated and free-flowing waterways, as dissolved nutrients become more concentrated in periods of lower discharge, and temperature increases favour the growth of algae. In the event of reduced discharge and the increase of stratification events, uncontrolled spread of species of blue-green algae, which can be toxic, must be feared, as has been observed already the case in the River Havel and, to some extent, in the River Elbe in the dry year 2003.

Future climate-induced clusters and increases in the intensity of hydrological and meteorological extreme events, such as long low-water periods with high air temperatures, may lead to deterioration in the oxygen situation, especially in impounded water reaches. Furthermore, rising water temperatures and, at the same time, longer residence times of the water will lead to an intensification of the degradation processes, so that a higher microbial consumption of oxygen may occur, particularly in the summer. At present, ecologically alarming situations of low oxygen content occur primarily in flowing waters that are regulated by barrages (the rivers Neckar, Saar and Havel). At high water temperatures, the internal metabolism of the body of water leads to higher consumption of oxygen so that during the periods of lower discharge in the summer half-year period, very low oxygen levels may occur. Compensating measures to increase levels of oxygen input derived from the atmosphere, such as additional passage over weirs, are expensive and require agreements with the energy industry, an option that is already being pursued for the River Neckar. Situations of intense precipitation may also exacerbate the oxygen situation. Then large quantities of degradable matter are washed into the receiving waters in a short time and consume oxygen. This is an acute problem in urban regions (e.g. waterways in Berlin), in backwater areas (e.g. in the Havel Lowlands after the Elbe flood in 2002, Böhme et al. 2005) and in tidal waters (e.g. after the Elbe flood in 2002). In free-flowing waters, the management of upstream reservoirs can have a major influence on the climate-induced changes or effects on oxygen content of the bodies of waters.

As a consequence of the expected rise in average water temperatures and the associated fluctuation/ reduction of oxygen content, health-relevant micro-organisms (e.g. faecal-coliform bacteria) could in future occur in higher concentrations or blue-green algae may produce highly active toxins. Besides the direct toxic effects of algal toxins, the increasing contamination of dredged material with algal toxins should be considered. Bacteria which cause infections represent an increasing risk factor in contact with water, sediments and dredged material during work in and at federal waterways.

Mass mortality of the Asian clam caused indirectly by temperature was observed in the Rhine in 2003 and

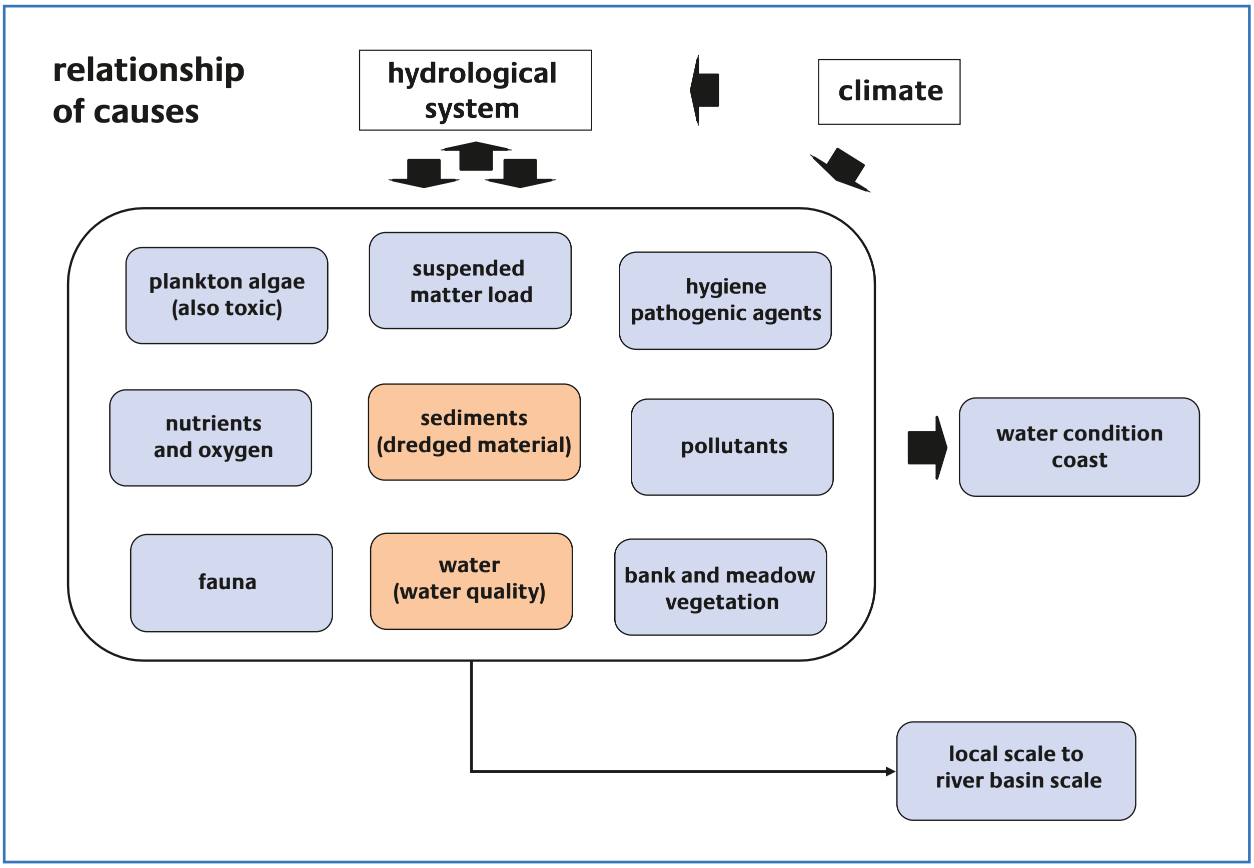

Fig. 1: Ecosystem components of federal waterways subject to influence by climate change

leads to major stress on the balance of matter and to considerable aesthetic impairment through rotting mussels.

Climate change will influence the structure and species composition of floodplain vegetation. Lower water levels will require adaptations of the waterways to guarantee uninterrupted navigability. Increased and more severe high water events will lead to an increase in high water protection measures. The reaction of floodplain vegetation to climate change with all its direct (hydrological changes) and indirect (modifications in land use) consequences must be studied in order to be able to distinguish between the effects of navigation-related adaptation measures and the impact of climate and to make projections.

Governmental research is often required to supply short term assessments on the topics mentioned previously and with regard to the maintenance and upgrading of waterways, often for whole river basins or large sections of rivers. This kind of short-term assessment may point the way for decisions at the political-administrative level, not only from the point of view of climate change. The model systems currently in use, the databases and the results produced are, however, not always oriented to the same spatial-temporal scale (from detailed level of specific planning procedures to large-scale) and are often not optimally adjusted to each other. There is still no systematic method for providing the required statements which are dependable and, at the same time, reflect current trends. In effect, the discussion on climate change makes this need apparent.

Table 1: Projects of KLIWAS Research Task 5: "Impacts of climate change on structure, ecological integrity and management of inland waterways"

Proj. No. 5.01	Climate projections for sediment budgets and risks due to cohesive sediments
Proj. No. 5.02	Impacts of climate change on nutrient and phytoplankton dynamics in navigable rivers
Proj. No. 5.03	Impacts of climate change on microbial water quality and their implications for dredged material management in inland waterways
Proj. No. 5.04	Impacts of climate change on patterns of organic pollutants in inland waters
Proj. No. 5.05	Impacts of climate change on stability and environmental relevance of hydraulic engineering materials in inland waters
Proj. No. 5.06	Impacts of climate change on the vegetation of flood plains
Proj. No. 5.07	Basics for the adaptation of faunistic evaluation methods due to climate change
Proj. No. 5.08	Indicators for impact evaluation of climate change and for adaptation options at river basin scale

4 Objectives of the Projects in Research Task 5

The changes established using dependable climate and runoff scenarios will be examined with regard to their impact on navigation and the environment (Table 1). The effects of possible climate-induced changes will be recorded, analysed and quantified so that utilisation as a navigation route can be guaranteed in the long-term, even under the altered conditions, while atill achieving the goals of nature protection and water management in federal waterways.

The quantitative investigations focus on the rivers Rhine and Elbe and on their sidewaters, some of which are regulated by damming. Individual, transferable studies will also be carried out on the Danube. The impact of climate change that can be expected on navigation, flowing waters, infrastructure installations and utilisation will be evaluated along with the associated risk potential. The goal is the timely introduction of adaptation measures, the identification of specific risk potential and the prevention of economic loss. In view of possible influences on the ecological condition, scenarios will be developed regarding the impact of climate change on inland bodies of water and their consequences for management of the latter.

The effects of climate changes on the sediment balance and the risk potential from contaminated old sediments will be established for the regulated Upper Rhine and for the German section of the Inland Elbe (Proj. No. 5.01). The impact of the new pollutant patterns on dredging measures will be ascertained and an analysis made as to whether the organic pollutants are changing as a result of climate (Proj. Nos. 5.01, 5.04). A possible deterioration in the hygiene situation in inland waterways will be described against the background of the types of utilisation and management of dredging work that have been discussed (Proj. No. 5.03).

The development of water quality, especially of algae und organic suspended matter, will be investigated using the water quality model QSim in regulated and free-flowing waters (Proj. No. 5.02). Tests will be made to determine when a dangerous development of toxic blue-green algae could occur in certain waters and whether mass mortality of bivalve mussels in the Rhine can be expected. In order to depict the temperature and oxygen stratification of impounded waters, which is most likely increasing, an already existing method using the QSim model will be optimised for determining the vertical zonation of oxygen and algae. Habitat suitability models for the bank and meadow vegetation will be developed or improved, taking into consideration the future discharge situation (Proj. No. 5.06).

Through these investigations, specialist knowledge will be provided for the WSV in light of the changed conditions, which can be integrated into guidelines and directions for action and into development processes for maintenance concepts. A further goal is to provide information on changes in the pollution to which tidal and coastal waters are subjected through contaminated sediments and suspended organic matter and algae that originate in inland regions.

Finally, a concept that uses the analysis of previous decision-making processes and the affected scales as a starting point (Proj. No. 5.08) will be prepared. The aim is to consider how various climate projections could affect the system "inland waterways" and how possible options for adaptation could influence relevant parameters as they are defined by the other projects in the context of the KLIWAS research programme. The existing cooperation of the higher authorities of the BMVBS in the scope of the BMVBS research programme will be used for this.

5 Summary / Looking to the Future

Possible influences of climate change on the ecological integrity of the federal waterways will be evaluated in the light of dependable estimations of changes of mean conditions and expected extreme events (high and low water events, maximum temperatures). In this way, the BMVBS and its higher authorities will be able to react early to the expected changes, introduce adaptation measures and reach agreements with the affected parties. Economic and ecological damage can be reduced or avoided and farsighted political measures placed on a solid, scientific foundation.

One important objective of Research Task 5 is to limit the influence of climate change on the bodies of water in the face of other influences, such as anthropogenic interventions in the geometry of the waterways. Knowledge of climatic changes will provide indications for future management in the catchment areas.

A significant improvement in the projection of the expected changes in the ecological condition of the waterways through use of the model system that is to be developed in the KLIWAS programme will benefit the planning tasks of the WSV. The evaluation of the pertinence of interventions will also be improved by making the path to decision-making during the planning stage more transparent and understandable.

Possible conflicts can then be identified and avoided at an early stage. The model results furthermore provide helpful indications for possible adaptations of hydraulic engineering measures that will be required to preserve the ecological integrity of federal waterways.

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A3 Reactions and Contributions to the KLIWAS Research Programme from Stakeholder Representatives

Perspectives for the Third World Climate Conference: Regional Information improves Global Climate Risk Management

Prof. Dr. Martin Visbeck, Leibniz Institute of Marine Sciences, IFM-GEOMAR, Kiel

The next World Climate Conference (WCC-3), which will be held in Geneva from 30.08.–04.09.2009 has set itself the target of establishing a global agreement which will permit nations and regions to improve risk management for the global climate.

The preliminary conferences have established commissions and programmes for the purpose of defining the global character of climate and its trends. For instance, at the First World Climate Conference in 1979, the World Climate Programme and the World Climate Research Programme were founded. The conference prepared the way for the Intergovernmental Panel on Climate Change (IPCC) which was set up in 1988 and was awarded the Nobel Peace Price in 2007. In 1992, the Second World Climate Conference established a global observation network (Global Climate Observing System) and drew up the United Nations Framework Convention on Climate Change (UNFCCC) which is intended to lead to a mandatory agreement in Copenhagen in the autumn of 2009 on the reduction of CO_2.

Climate change, resulting from both natural and anthropogenic causes, is affecting living conditions around the world. Climate change is leading to increases in air and water temperatures and to a rise in sea level. From many perspectives the change is marked, but it may vary regionally in its character. Floods and droughts may also be caused by climate fluctuations. According to the present state of knowledge, some aspects of climate fluctuations, such as El Niño events, can be predicted many months in advance. Other phenomena, such as the North Atlantic Oscillation, which affects the winter climate in Europe, can (probably) not be foreseen with usable precision. The IPCC has developed climate scenarios for the period until the year 2100 which allow for differing possibilities in the implementation of climate protection objectives or in world economic development. The character of climate change will thus depend mainly on the fulfilment of global climate objectives. If these are weak, mankind will be forced to adapt to climate change, which in some cases will have dramatic regional effects.

The Third World Climate Conference aims to create a platform which will enable the nations of the world to exchange climatic data and predictions relevant to decision-making processes, in particular with a view to the next 30 years. The decision-makers in many fields that depend on climate, such as water management, agriculture, the fishing industry, health, forestry, transport, tourism, energy and disaster management are increasingly alarmed at the risks of climate change and also of climatic fluctuations – especially those of decadal time scales. The current ability of climatic risk management to interpret the available climatic data appropriately and to generate recommendations for action is not yet sufficiently advanced. In order to provide data relevant to decision-making processes, a new, common and internationally shared approach to the task will be necessary.

At the conference, politicians, scientists and experts from climate-sensitive economic fields will debate the climatic data and predictions which are the prerequisite for effective strategies for adaptation to climate change. Subsequently, specific implementation options are to be discussed. The organisers are suggesting the initiation of a global framework for climatic services (Global Framework for Climate Services, GFCS). The objective of this climatic service system is to "enable climate adaptation and climate risk management through the incorporation of science-based climate information and prediction into policy and practice at all levels".

The GFCS comprises four main elements:

1) Observation and monitoring

2) Climate research and modelling

3) An information system for climate services

4) A programme for furthering the application of climate services

The first two fields are already well-established internationally, but must be further expanded. The two other fields are essentially new concepts.

The information system for climate services should guarantee the development of user-specific climatic data and the flow of information between the different suppliers of climatic data at all levels from global to local. It is based on proved global programmes and institutions and their infrastructure and working methods, and will continue to develop these. With measures for the promotion of the development, provision and application of climate services, the GFCS will contribute to the lessening of poverty and to the improvement of climate-related disaster management and, thus, to the implementation of internationally agreed objectives. Predictions covering periods ranging from one season to several years should assist people such as farmers in their decisions regarding cultivation of crops and harvesting and provide early warning of extreme events. Scientifically supported climatic data should be made available to societies promptly in order to facilitate planning for the distribution of water supplies, foodstuffs, medication and other services. Improved climate services will enable societies around the globe to deal with climate risks and chances in a better and more professional way.

Regionally oriented activities, such as the German KLIWAS programme, can function as good examples of transdisciplinary cooperation between the fields which generate climatic data and the decision-makers who use this to reduce their climate risk.

The organisers of the WWC-3 would welcome participation with regard to the contents of KLIWAS at the conference. Other nations could benefit from the successes and challenges of the KLIWAS programme.

Further information on the Third World Climate Conference can be found at: www.wmo.int/wcc3/ or www.dgvn.de/wcc3forum.html.

Statement from the Bund für Umwelt und Naturschutz (BUND) (League for the Environment and Nature Conservation, Germany)

Winfried Lücking, BUND-Flussbüro (Rivers Office) Berlin

The BUND welcomes the KLIWAS research programme. For many years we have, from our side, been calling for climate change to be taken into account both in maintenance and upgrading of rivers in their function as federal waterways, and have received repeated criticism in this matter.

I would like specifically to thank the BMVBS for taking up this issue and for the contribution it will thus make to objectivity in the future debate.

Statement from the Bundesverband der Deutschen Binnenschifffahrt e.V. (BDB) (Federal Union of German Inland Navigation)

Jörg Rusche, Managing Director, BDB

Ladies and Gentlemen,
As the Federal Union of German Inland Navigation, we would like to thank you for initiating the work on the KLIWAS project.

We are very pleased that the announcement of the Secretary of State, Ms. Roth, at our parliamentary evening on the topic of “Inland navigation in a changing environment” is now being implemented.

The research programme will certainly contribute to an objective discussion on upgrading and maintenance measures on federal waterways. We hope that specific statements on climate change with reference to an individual river basin will now be possible for the first time.

We offer you our support for the research programme in the form of expertise in the field of logistics, for a better definition of the opportunities and challenges that present themselves on the level between inland navigation and your customers in industry, trade and tourism.

We wish you every success with the research programme!

Statement on the KLIWAS research programme from the Elbe-Saale-Vereine (Associations of the Elbe-Saale Region)

Manfred Sprinzek, President of the Verein zur Hebung der Saaleschifffahrt e.V. (NGO for the enhancement of shipping on the rivers Elbe and Saale)

The Verein zur Hebung der Saaleschifffahrt (VHdS) was founded in 1996 with the aim of reviving navigation on the River Saale and connecting the Saale to the European inland navigation network by completing the upgrading of the Saale in a manner that is environmentally-friendly, cost-effective and unaffected by high water events.

After twelve years of diligent work, the Verein zur Hebung der Saaleschifffahrt (VHdS) has succeeded in finding a good and acceptable compromise between economic interests and environmental protection in cooperation with the Federal Waterways and Shipping Administration of the German government. The first necessary public law proceedings concerning the construction of the Tornitz lock canal were concluded in October 2008 with a positive result. In order to strengthen the competitiveness of businesses in the Saale region through shipping, the planning approval procedure must now be initiated as quickly as possible. We are confident that this democratic administrative procedure will also take note of the public's interest in the completion of the upgrading of the Saale and that the Tornitz lock canal can soon be completed.

This will secure current jobs and permit the creation of new jobs.

The Verein zur Förderung des Elbstromgebietes (Association for the Development of the Elbe River Basin) and the Sächsische Hafen- und Verkehrsverein (Saxon Ports and Transport Association) are committed to placing the potential and significance of the River Elbe in terms of efficient inland navigation more in the focus of public attention. They are therefore calling for the River Elbe to be returned to the state which already existed before the Elbe flooding in 2002, by the year 2010, through maintenance work by the German Federal Waterways and Shipping Administration. A water depth of 1.60 metres must be available again on at least 345 days per year! As container and freight traffic requires, on average, a depth of about 1.40 metres for inland vessels, achieving this state would guarantee year-round, cost-effective navigation on the Elbe.

Together with the Verein zur Förderung des Elbstromgebietes and the Sächsische Hafen- und Verkehrsverein, we welcome the decision of the federal government to investigate and implement a strategy for adaptation to climate change. This will create greater security and more room for manoeuvre for all players in the areas of navigation, ports and the inland navigation enterprises which are affected by the impact of climate change in Germany.

This represents a great step forward compared to the debate in society up to now on the impact of climate change on navigation in Germany, particularly on the rivers Elbe and Saale. Until now, public debate in our region has led to the impression that climate changes would have a disastrous effect on the Elbe and Saale, and that, in future, navigation would become impossible, because of low water levels. It is high time that an alternative is presented to these terrifying scenarios.

It is important and timely that, using the expert knowledge of the National Meteorological Service of Germany, the German Maritime and Hydrographic Agency, the Federal Institute of Hydrology (BfG) and the Federal Waterways Engineering and Research Institute, the scientific basis of climate impact research as relevant to waterways and navigation should be investigated independently and competently and in an interdisciplinary way, and strategies for adaptation be drawn up.

For the free-flowing River Elbe, and for the River Saale, it is important to determine future climatic trends with the greatest possible certainty using current climate models, in order to derive regional projections for the Elbe and Saale. The drawing up of a prediction for water supplies and future conditions for navigation from these research results would also be worthwhile.

For many centuries, hydraulic engineers in Germany have clearly proved their skills and expertise. Storage and retention of water is, from a technical point of view, of importance not only for navigation, but also for ecology, water management and agriculture.

A depiction of the impact of climate change on navigation conditions on the Elbe and Saale rivers, along with the hydraulic engineering options required in order to be able to react wisely to these, would be desirable.

The Elbe-Saale Associations wish the KLIWAS research programme "Impact of Climate Change on Waterways and Navigation in Germany – Options to Adapt" and the First Status Conference which is being held in Bonn today and tomorrow every success!

Acqua Alta 2009 – International Conference and Exhibition on Consequences of Climate Change and Flood Protection

Annika Klar, Project Manager, acqua alta, Hamburg Messe und Congress GmbH & Michael Gelinek, Managing Director, ConTrac GmbH

10th–12th November 2009, Congress Center Hamburg

acqua alta 2009 is a conference and exhibition which focuses on expert debate on the topics of climate change and climate protection and their impact in the field of flooding and disasters. Politicians, economic experts, scientists and specialists from cities and municipalities can learn about and discuss the latest developments and strategies regarding the many and varied issues regarding climate change.

Lasting for three days, *acqua alta* covers all aspects of climate change issues and climate impact from the technical and ecological perspectives.

A special forum "Waters in coastal and inland regions" is one of the events planned; this will highlight the synergies of the KLIWAS research programme on the management of high and low water events and coastal protection along with other topics.

B) First Results of the KLIWAS Project "Hydrology and Inland Navigation" (4.01)

B1 Vulnerability of the Rhine Waterway and Economic Aspects

KLIWAS Pilot Project 4.01 "Hydrology and Inland Navigation" – Objectives and Framework of Study

Enno Nilson (BfG)

1 Introduction

The KLIWAS Pilot Project 4.01 "Hydrology and Inland Navigation" was launched in the year 2007. At first glance, this timing may appear surprising, as it seemed at that point that, in public opinion, everything was already known about climate change.

On the one hand, the Fourth Assessment Report of the IPCC had been published, which, among other things, provided the final certainty that global temperatures are rising. On the other, there had been the hot summer in the year 2003 which was associated with a distinctive low water situation. In the public debate, these two factors became enmeshed – a situation which was partly furthered by contributions from the fields of the media and science. The year 2003 thus became the example for "actual climate change" and "an experience of the future".

The result was, firstly, considerable nervousness in the general public and alarm on the part of users of waterways, both of which still persist. Secondly, it created debate and strong pressure for specific adaptation measures in the structure of inland waterways (cf. MOSER et al., 2008).

The BMVBS confronted this situation early and brought forward the work that had been assigned to the BfG on Project 4.01 "Hydrology and Inland Navigation". In particular, the BfG began its work along with its partner institutions, the Max Planck Institute for Meteorology (MPI-M), the Development Centre for Ship Technology and Transport Systems (DST), the University of Würzburg and the University of Applied Sciences Rottenburg in June 2007, with the aim of:

a) determining the sensitivity of inland navigation and the economy to possible climate impact (see contributions by HOLTMANN & BIALONSKI and SCHOLTEN & ROTHSTEIN in this volume)

b) evaluating the state of knowledge and the base data for climate impact related to inland waterways (see contributions BELZ & GRATZKI, JACOB et al. and CARAMBIA in this volume)

c) evaluating – on this basis and, thus, at a later point in time – existing and possible new options for adaptation.

The work concentrates mainly on the River Rhine, the most important inland waterway in Europe. The base data and concepts will, nevertheless, be prepared for Central Europe as a whole. The work will soon be continued for other river basins, such as the Elbe and Danube (Fig. 1).

2 The Study Concept

Climate impact is generally studied by using model chains. In each segment of the model chain there are greater or lesser uncertainties which continue in a cascade throughout the course of the model chain (cf. BMVBS, 2007). The causes are, for instance, assumptions regarding future (global economic) developments which must be made for the emissions scenarios or abstractions that are necessary for a description of the system structure of inland waterways in model form. The uncertainties become apparent in the fact that in every segment of the model chain not just one "future" is projected, but a range of several such "futures".

KLIWAS is concerned firstly with demonstrating the span of the corridor of possible developments. Next, an evaluation of the individual development paths (projections) will be made, to point out particularly plausible and valid development corridors within this span. Finally, a restricted number of paths with similar probability will be selected as scenarios, where possible.

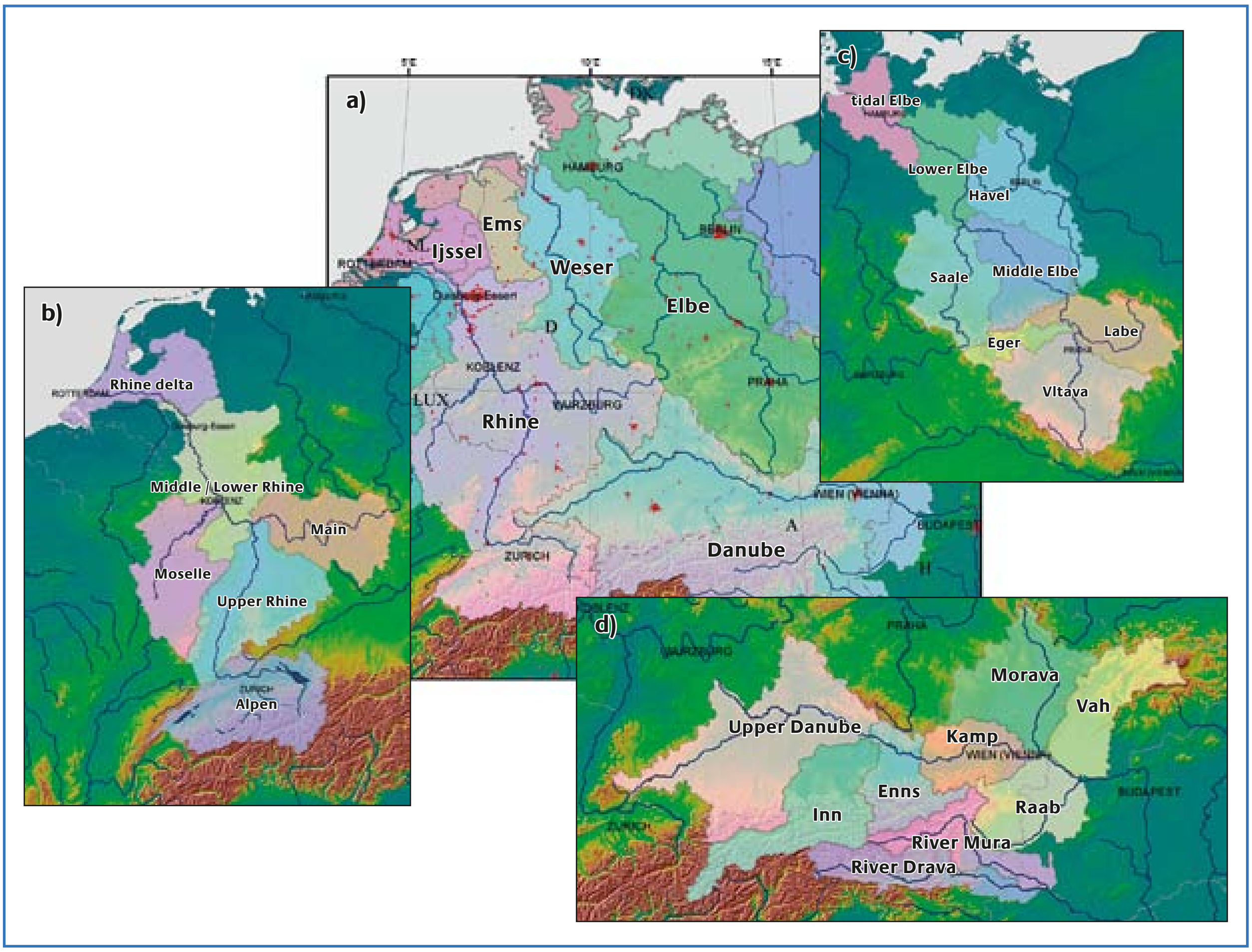

Fig. 1: Study fields of KLIWAS 4.01 (provisional)

2.1 Model Chain

At the beginning of the model chain developed by the KLIWAS project "Hydrology and Inland Navigation" are the scenarios for greenhouse gas emissions and concentrations; using these as a hypothesis, global climate models, and regional climate models that are coupled to the latter, project meteorological data, including "hydrometeorological data" (temperature, precipitation and other parameters relevant to evaporation) which, in turn, are integrated into hydrological models. This data is then converted into discharge data, taking into account the storage characteristics of the substratum, land use and orography. Model chains often end at this point. In the KLIWAS project "Hydrology and Inland Navigation", however, other "modules" follow.

Not only discharge characteristics are of particular importance for navigation, but also the hydrodynamic results which can be derived from these. A hydrodynamic model therefore follows in the model chain, with which the discharge data is translated into data on water levels and flow velocities. Another interesting aspect for navigation is the question of how the

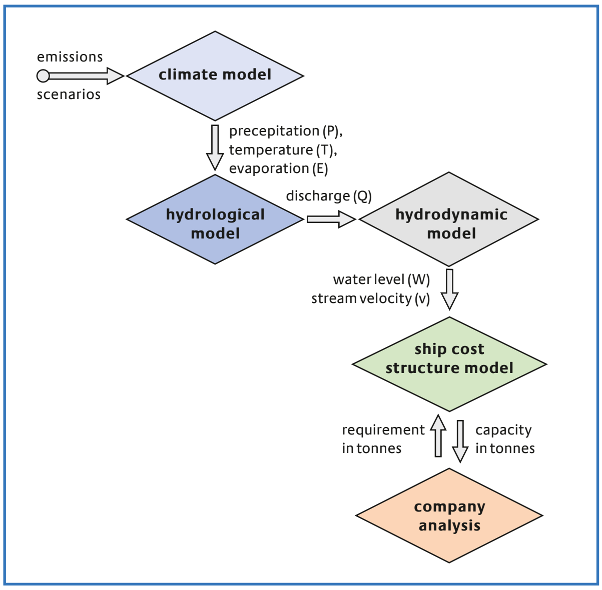

Fig. 2: Model chain of the KLIWAS project "Hydrology and Inland Navigation"

respective navigation channel conditions affect ship operations. A cost structure model is used, on the one hand, to quantify how overheads (costs relating to time and performance) will develop as a result of these conditions and, on the other, how the available transport capacity will change – by integrating the fleet structure and transport flows (into the model).

Another model is used to investigate how flexibly or sensitively the forwarding industry can generally react to changes in transport capacity, that is, to possible consequences of climate change. For this, an approach has been chosen which focuses on the actual vulnerability as perceived by those affected and on their specific reactions. The reactions aim, for instance, to make the transport requirements flexible and to adapt them to the fluctuations in the capacity of the mode of transport. The corresponding data will be collected by means of a survey of companies. This approach is different to that of macro-economic methods which assume that the economy functions in a certain way and simulate the reaction of the entirety of all companies, as it were, from the top down.

2.2 Span

Many impact studies are based on the results of only one or a few climate projections and the parameters derived from them. However, it is a well-known fact that every model has its own strengths and weaknesses and that only a certain part of the actual span of the projections will be recorded. For this reason, multi-model approaches are "best practice" and compliant with the Intergovernmental Panel On Climate Change (IPCC, 2007) and the German Strategy for Adaptation to Climate Change (Cabinet of the German Federal Government, 2008). KLIWAS "Hydrology and Inland Naviga-

Table 1: Overview of the base data processed so far in the work of KLIWAS. The processing status of March 2009 is shown in bold type. The model combinations that have been dealt with and the resulting projections are highlighted in red.

3 emission scenarios	**6 global climate models**	**10 downscaling methods**	**2 hydrolog. models 1 hydrodyn. model**	**cost structure model**	**company analysis**
• **"extreme" (A2)** • **"intermediate" (A1B)** • **"moderate" (B1)**	• **ECHAM5** • **BCC-BCM2.0** • **ARPEGE** • **HadCM** • CGCM3 • IPSL-CM4	• *STAR2.0* (3) • *WETTREG2005* (9) • **CLM** (4) • **REMO** (5) • **HadRM** (1) • **HIRHAM** (2) • RACMO • RCA (= 24) • CRCM • PROMES	• **HBV 134-SOBEK** • LARSIM-SOBEK	**6 types of vessel:** • **Gustav Koenigs vessel type** • **"Großmotorschiff" (110, 135 metres)** • Johann Welker vessel type (Europe ship) • Jowi class container vessel type • coupled convoy • pushed convoy	• around. 100 companies, **current no. of returns: 40%** • **14 ports** • **7 sectors**
• **"observed" (C20)**	• **reanalyses (ERA40)**	• **hydrometeorological observations**	• **measured gauges**	**2 categories of freight:** • **bulk goods (weigt)** • containers (volume)	

tion" relies on diversity at all levels of the model chain (Table 1) and combines all available climate projections for Central Europe, including the results of the current EU project ENSEMBLES (ENSEMBLES Partner, 2009) and the ZWEK project (DWD, 2008).

All conventional emissions scenarios and all global climate models (in some cases, several runs of the same model) which have been downscaled in a variety of ways for Central Europe / Germany are taken into consideration. Through the couplings of different scenarios, global climate models and downscaling procedures, around 30 runs can be obtained at the level of downscaled model output, 24 of which have been processed so far in the context of the KLIWAS project "Hydrology and Inland Navigation". These runs were converted into discharge using the hydrological model HBV. Further runs, using additional hydrological models, will follow. In the field of inland navigation and economy, diversity is important, too: six different vessel types with two different categories of freight and numerous companies from seven different economic sectors which transfer their educts and products at 14 different ports were studied.

2.3 Water Traffic Management – Evaluation and Analysis

The evaluation and analysis of this abundance of projections and base data (cf. 2.2) is carried out with reference to specific hydrological and water traffic management questions which are dealt with in the KLIWAS project "Hydrology and Inland Navigation". The individual modules of the model chain are evaluated by comparing the simulations with observation data within a control period that lies in the past (here: 1971–2000).

As it is a well known fact that there are also inaccuracies in observation data, caused, for instance, by measurement errors, different observation products are used for some links of the model chain. Regarding the "climate change signals", the evaluation is carried out by comparing the control period (1971–2000) with the conditions in the "near future" (2021–2050) or the "distant future" (2071–2100).

The evaluation criteria vary according to module (Table 2). The global climate models are, for example, evaluated in terms of a so-called objective weather type classification scheme (Dittmann et al., 1995) for the purpose of determining whether they are capable of simulating typical drought-causing weather situations. If this capability can be proved, it will in future be possible to make statements on the basis of this data regarding possible future frequency and duration of these weather situations. On the level of downscaling procedures, the focus is on an evaluation of hydrometeorological parameters for specific river basins, using a comprehensive catalogue of statistical criteria. Here criteria such as the ability of individual methods to simulate extreme situations (e.g. maximum number of dry days), are of special relevance. The hydrological-hy-

Table 2: Overview of the evaluation criteria and processing steps applied to the base data in KLIWAS so far (cf. Table 1). The processing status of March 2009 is shown in bold type.

3 emission scenarios	6 global climate models	10 downscaling methods	2 hydrolog. models 1 hydrodyn. model	cost structure model	company analysis
• - - -	• **objective weather type classification** (Dittmann et al. 1995) • North Atlantic Oscillation (zonal index)	• **validation, analysis and bias correction of** • **hydrometeorological fields** for • 12 subcatchments of the Rhine, using • 25 statistical criteria	• **validation and analysis using Q and W** relating for • 15 segments of the Rhine, using • 20 statistical criteria	• **analysis of sensitivities using** • **detailed ship operating costs and** • **specific costs** • calculation of relation-specific transport capacities	• **analysis of sector-specific sensitivities** • **calculation of current transport requirements**

drodynamic simulations are also evaluated on the basis of a catalogue of criteria. This is done, on the one hand, with a view to fundamental changes in the hydrological system (for instance, typical annual course of the mean discharge) and, on the other hand, with an emphasis on specific parameters with relevance to navigation, such as the duration of periods under certain water level thresholds in shallow river sections.

A validation based on observation data is not easy for the modules "inland navigation" and "forwarding industry", as their basis is purely empirical. However, climate change signals are assigned to these sectors, too. In this way, monetary effects of changed navigation channel conditions can be evaluated statistically, and in detail, with regard to various aspects of the cost of ship operations. On the part of the shipping industry, the sensitivity to current variations of transport capacities will be used to draw conclusions with regard to possible consequences of the simulated future capacities.

3 Summary and Evaluation of the Results obtained so far

The following contributions in this volume show that comprehensive results are already available which are extremely interesting for a vast number of players on and along the inland waterway, the river Rhine.

- KLIWAS already has one of the most complete model chains in the field of climate impact research for water traffic management.
- KLIWAS already has one of the most complete ensembles of climate and discharge projections for the River Rhine.
- KLIWAS is already supplying important fundamental knowledge for the research network and political advisory services (CHR, ICPR, contribution to CCNR conference in Bonn on 24th/25th June 2009).

However, it is equally clear that the work is not finished. The findings described in this volume are therefore of a provisional nature.

- The complete range of simulations is not yet available.
- Some climate model runs (e.g. of the ENSEMBLES project) are still "work in progress".
- The evaluation of the existing projections is still incomplete.

The results available at the present moment are not adequate for the evaluation of further issues (e.g. adaptation measures). The concept of a comprehensive and methodologically resilient evaluation of all basic knowledge and sensitivities that has been presented still has to be fully implemented. Part of the philosophy of KLIWAS is the avoidance of hasty and, thus, of unobjective or poorly founded statements (see also: Objectives of Task 1).

- The provisional data will not be made available outside the KLIWAS network until satisfactory checking and evaluation has been carried out (see also: Objectives of Task 1).
- A responsibly substantiated decision on options for adaptation is at present not possible.

Literature

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Vulnerability of the System Structure “Inland Navigation”

Michael Heinz (WSD), Jens Stenglein (WSD) & Thomas Rosenstein (BMVBS)

1 Utilisation of the Waterways

The German waterways form the backbone both of the west-east and of the north-south axis of the European waterways network. However, the usability of the important international waterways, the Rhine and Danube, for transport purposes, depends on the water level. This is also true of the Elbe and Oder rivers.

As the Rhine plays the most significant role in the waterways network of continental Europe in terms of traffic density, the interaction between discharge-related and transport economics-related utilisation will be described in more detail, using the Rhine as an example.

The present vulnerability, that is, the interaction between discharge and utilisation with disadvantages for the economic aspects will be explained on the basis of the current usability; an eventual climate-induced change is not taken into consideration here.

Present-day traffic on the Rhine is characterised by the passage of 100 to 500 ships daily. Many shipping companies use the Rhine around the clock, on up to 365 days of the year.

A characteristic feature of the strong involvement in international logistic processes is the comparatively high proportion of navigation during the night. This varies between 27 % for pushing traffic on the Lower Rhine and 12 % for independently powered motor vessels. Because of the high standards of upgrading and the strong industrial presence, extremely large vessels with a loading capacity of between 2,000 and 4,000 tons and pushing units with a transport capacity of up to 24,000 tons in convoys of 6-lighters travel on the Rhine.

Good training for ships’ masters, high standards of equipment for the ships and reliable accessibility of the waterways allow for safe navigation at all water levels

Fig. 1: Freight traffic density of marine and inland navigation on the main network of the federal waterways

and in all types of weather. The accident rates for the Rhine – despite constantly increasing traffic volumes – have, in fact, for many years shown a downward trend.

The freight structure in the Rhine is characterised by a bulk cargo percentage of more than 80%. Ores and metals, coal, construction materials, oils and gases and chemical products make up the major share. The percentage of hazardous goods is 15 %, which is not only large; these goods are also transported in a manner that is both extremely safe and environment-friendly. The rapidly increasing container traffic makes up approximately 5–7 % at present, and while this is not much from the point of view of volume, it represents an increasingly important type of packaging in regard to added value and is significant in terms of the number of transports (2.6 m TEUs [twenty feet equivalent unit] on the Lower Rhine).

2 Developments – Annual Transport Volumes, Traffic and Ships

The traffic volume (annual transport volumes) on the Rhine has risen since 1945 from 15 m freight tonnes per annum (tpa) initially to more than 100 m freight tpa in the 1960s and has now reached 172 m tpa. on the Lower Rhine. The predictions of the current Bundesverkehrswegeplan (BVWP– Federal Transport Infrastructure Plan) for the year 2015 assume a traffic volume of around 200 m tpa.

In the last 60 years, the transport structure has undergone widely differing stages of development. While in the 1950s and 60s, the transport scene was characterised by a very large number of vessels, fewer ships are in use today, despite the increase in transport volumes.

The development of vessel size on the Rhine continues to feature a trend towards larger units. The average vessel size is growing at 1.0–1.5 % per year – and the more so, since the üGMS (extra-large motorised freight ship) has become established in the market over the last 15 years. It is expected that the numbers of this new ship type will increase from 13 vessels (in the year 2000) to more than 170 by the year 2025.

Overall, for the period from 2000 to 2025, it can be expected that the predicted numbers of motorised freight ships will decrease by 18 %, while the size of the ships will increase by 35 %.

3 Vulnerability

In relation to changes brought about by climate change, the vulnerability of the system structure “inland navigation” is often defined merely in terms of the occurrence of long periods with low water levels. By comparison, restrictions on utilisation as a result of high water,

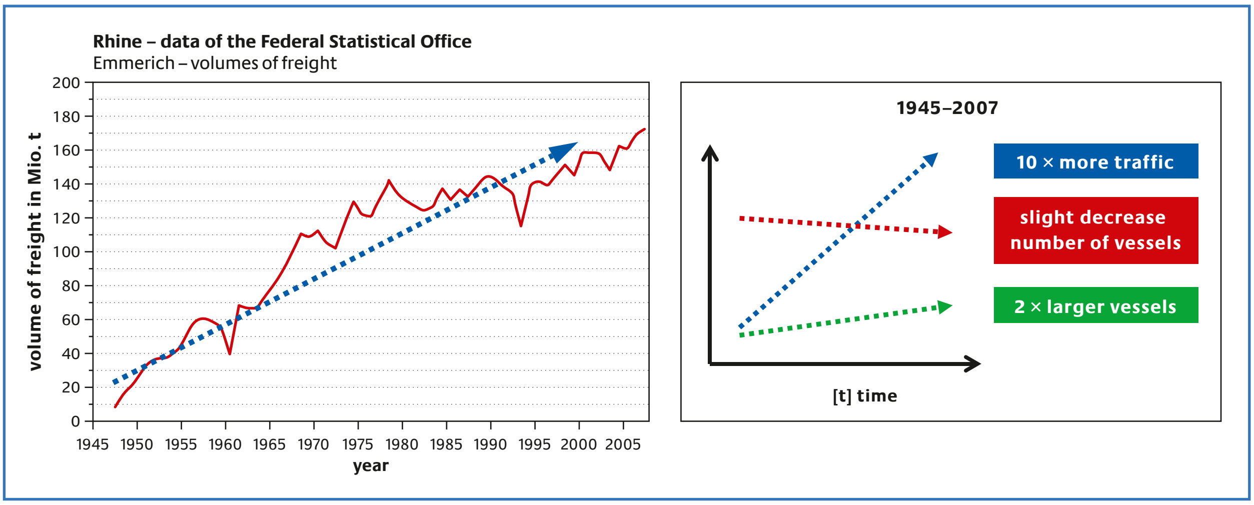

Fig. 2: Development of traffic volumes, vessel sizes and numbers of vessels

and sometimes the closure of waterways because of average or for special events impair the availability of the Rhine, more frequently and less predictably than low water.

In addition, much of the traffic on the Rhine is destined for, or originates from the canals or tributary rivers of western Germany (e.g. Moselle, Main or Neckar). Thus, their availability also influences the vulnerability of the entire transport chain. Here, there is an additional "disrupting factor" for the transport chain in the form of occasional restrictions due to ice formation.

In the stretches with particularly high traffic density, the Rhine is a free-flowing river (see Fig. 1); its usability is therefore dependent on the water level. A water depth of at least 3.0 metres all year round can be guaranteed only in the regulated section of the Upper Rhine between Iffezheim and Basel. However, because of the strong affinity of the transport chain to the Rhine outlet ports, this depth is only usable independently of discharge conditions and, thus, without restriction, for a small percentage of regional traffic.

As a result of the continually increasing vessel size, ship owning companies and loading agents must load their ships in accordance with discharge conditions on many days of the year. Using the example of an average year (2007), Figure 3 shows that at the gauge in Cologne, in comparison with the Europe ships that were widely used 30 years ago (loading depth c. 2.50 m), loading of the present-day large motorised freight ships (GMS) or extra-large motorised freight ships (üGMS) with a maximum draught of up to 3.8 metres is dependent on discharge conditions on around 200 days per year; at the Kaub gauge on the Middle Rhine, with 260 days/year, this figure is even higher.

If a maximum permitted draught of only 1.5 or 2.00 metres is possible for the large üGMS or GMS type of vessel, the transport volume is reduced by around 40% or 20% respectively. In spite of these fluctuations in usability, in the last decades, the shipping trade has decided, for economic reasons, to use larger vessels, as the economic advantage still outweighs the disadvantages.

To the same degree, transport utilisation has become more intensive and denser in recent years. More 24-hour transports and "just-in-time" transports, fewer warehouses on land and more warehousing in ship space, as well as greater internationalisation of the flow of goods, have led to waterway transport becoming more vulnerable to disruption.

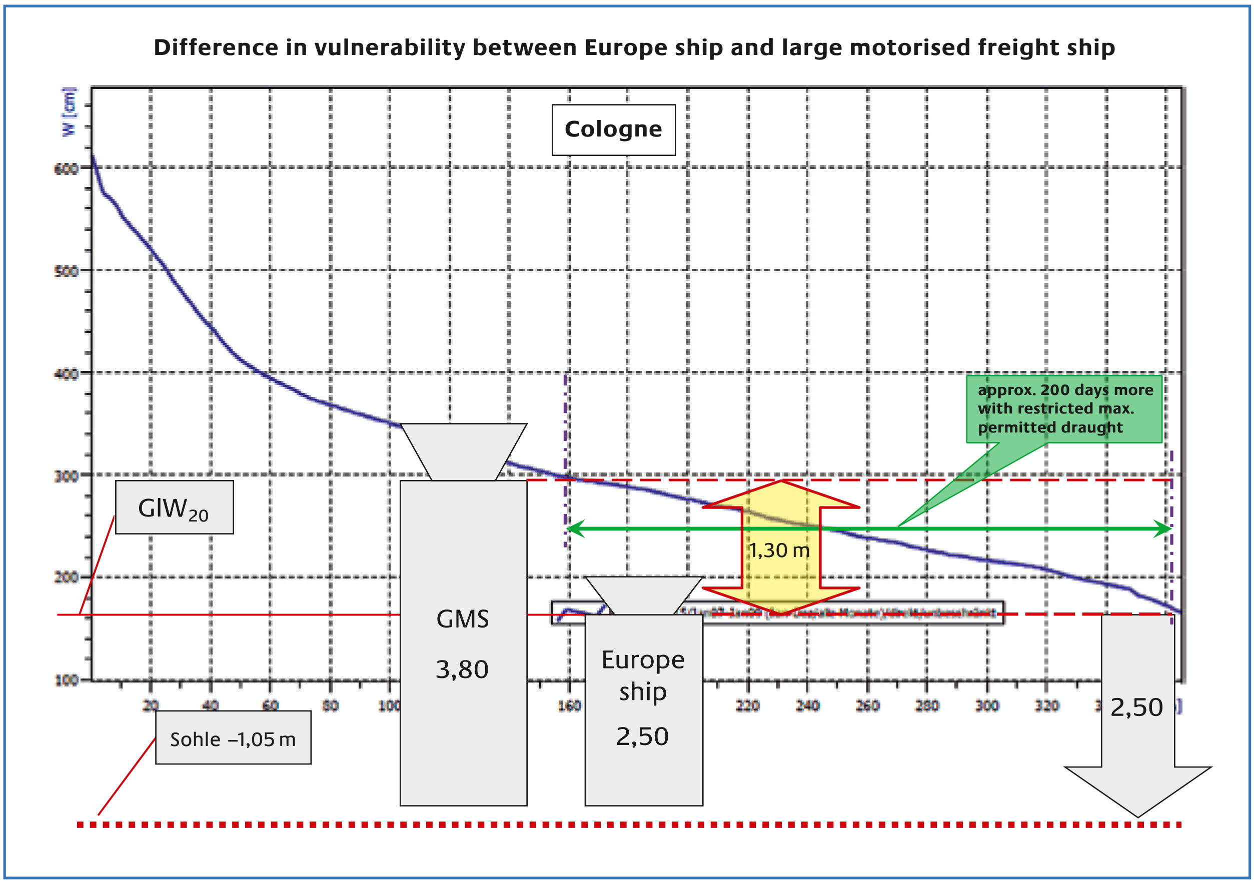

Fig. 3: Duration curve of the Cologne gauge (2007/2008) with usability comparison for GMS – ES

4 Improvements in Utilisation 1945–2010

In recognition of the development of traffic and vessel size, numerous construction measures for improving the maximum permitted draught have been undertaken along the Rhine in recent years.

With the equivalent water level (GlW_{20}), which is available on at least 20 days in the long-term mean, improvements of 20–40 cm in the depth of the navigation channel were achieved on certain sections of the Rhine. Currently, the morphological fluctuation of the navigation channel bed at bottlenecks, which dictates maximum draught, can be adjusted by appropriate methods, such as dredging work.

5 Approaches for Action – Navigation and Infrastructure

In particular the long low-water periods of the years 2003 and 2005 clearly demonstrated that the shipping capacity reserves available on the market were barely adequate for events of this nature. Since then, the available shipping capacity has increased through the construction of new vessels. In addition, further considerations are being made with a view to modifications in industrial warehousing strategies. For considerations on the in-pricing of system reserves to be successful, these must be accepted by the players in the market.

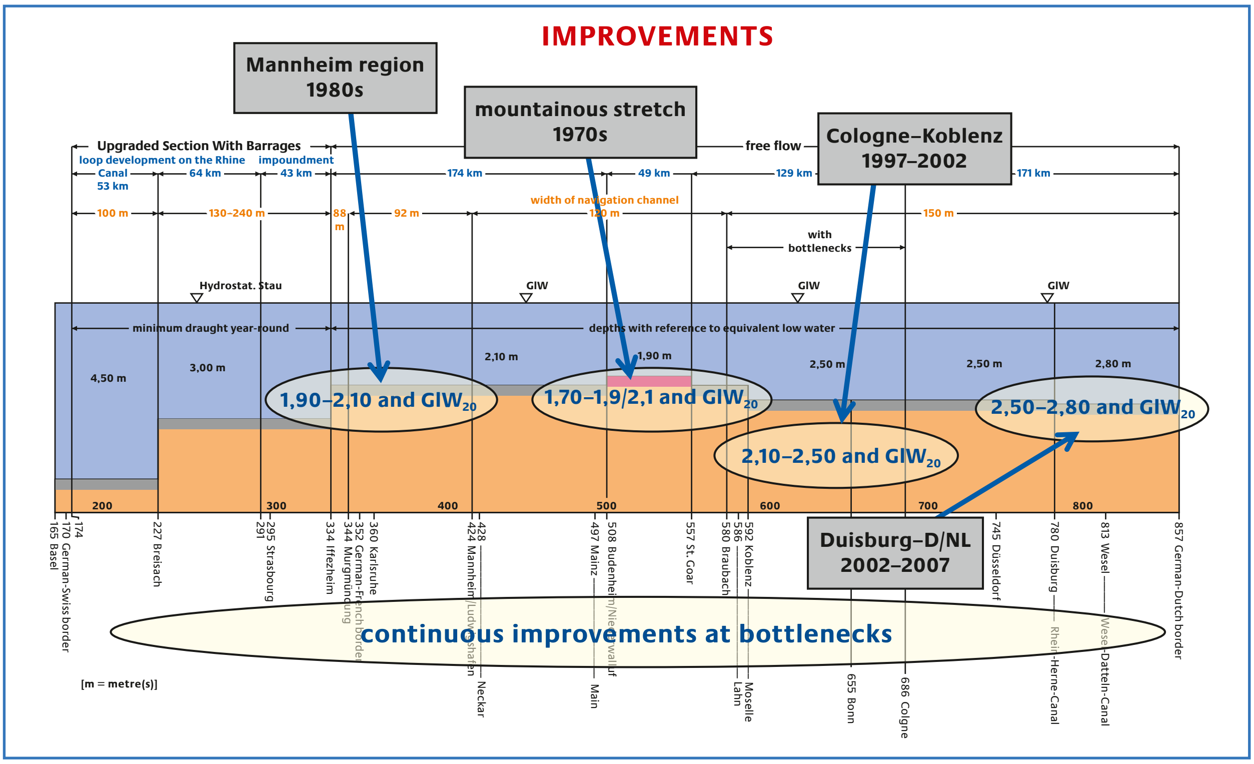

Fig. 4: Overview of measures showing improvement in maximum permitted draught

In terms of infrastructure, improvements in information and predictions – and thus, also, in the feasibility of planning for loading activities – have become established in the last few years. The extension of the water level forecast from 2 to 4 days, traffic bottleneck warnings and announcements of depth lines via the ARGO programme / Inland-ECDIS (Electronic Chart Display and Information Systems for Inland Navigation) have improved usability and calculability.

Further improvements are conceivable within the foreseeable future. The expanded integration of AIS (Automatic Identification System) into a more flexible design of the navigation channel width (in favour of more depth) and further local optimisation measures for dealing with bottlenecks are also items in the current planning activities of the waterways administration.

6 Summary / Looking to the Future

Navigation on the Rhine waterways has generally become more vulnerable at a high level, as a result of the developments in ships themselves and through the more intense logistical networking. However, it can also be asserted that the changes in transport economics (ships, logistics) of the last 10–30 years were greater than the changes in discharge as a result of climatic influences.

Utility and usability have increased, while becoming, more mobile and volatile, and the requirements for utilisation – alongside high expectations of reliability – have risen.

For the future, as regards the Rhine, it can be said that there is still large potential for exploitation in the system ship/waterway which could be suitable for the environmentally-friendly absorption of the growth factors as a result of traffic predictions for 2015/2025 and the repeated circulation of the ships caused by climate change.

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The Influence of Extreme Water Levels on Cost Structure and Competitiveness of Inland Navigation

Berthold Holtmann (DST)
& Wolfgang Bialonski (DST)

1 Introduction

The impact of climate change is diverse and affects many different areas. These include industries which rely on reasonably-priced transport of bulk cargos and which for that reason have frequently selected their locations in the vicinity of waterways. These are, above all, the coal and steel industry, the energy industry and the chemical industry, all of which focus their transport requirements to a high degree on inland navigation, that is, on a mode of transport which is uniquely dependent on circumstances of climate and weather. This dependence results, firstly, from the available water depth, which through its impact on the maximum permitted draught has a decisive influence on transport costs and, secondly, from the fact that the reliability and safety of this mode of transport are affected by extreme water levels.

This lecture will explore the influence of extreme water levels on the cost structure and competitiveness of inland navigation.

2 Influencing Variables and Model Approach

The costs of inland waterways transport include various items; the most important pools of costs besides depreciation and capital costs, repairs and material, insurance, overheads and administrative costs and personnel costs are, above all, costs for fuel and lubricants.

Transport costs are mainly determined by the actual fairway conditions, that is, principally the waterway depth and the hydrodynamic properties of the inland navigation vessels, i.e. hull form, propulsion characteristics etc. By its influence on the possible draught, the water depth determines, on the one hand, the

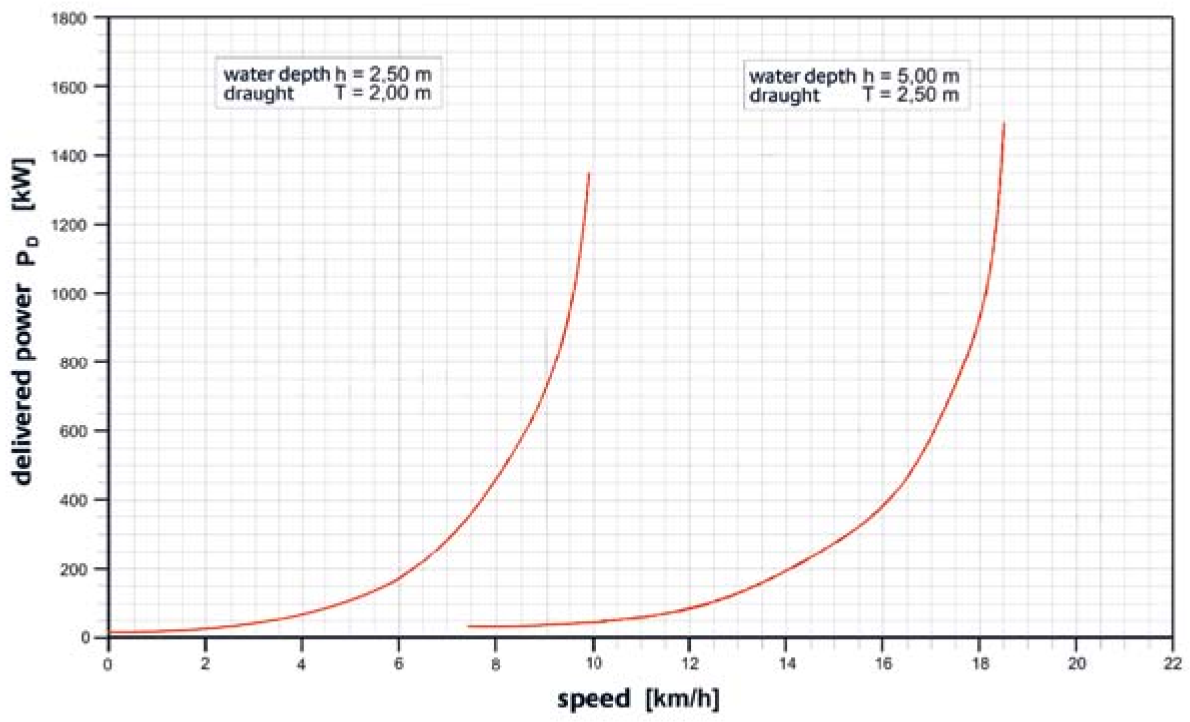

Fig. 1: Power-speed profile for vessel type "Europe ship" (Johann Welker) (speed against water)

maximum payload of the ship and, consequently, the capacity utilization and, on the other, the power requirements and speed and, in this way, the time for a roundtrip and overall costs, or rather the specific costs for transport by ship. While the water depth of one specific cross section in the entire transport route determines the maximum draught ("water depth affecting maximum loading line", e.g. Bingen/Oestrich/Kaub for relations in the Upper Rhine), power requirements (such as fuel consumption) and speed are, even at constant water levels, influenced throughout the course of the waterway by continuously changing water depths ("water depths affecting propulsion").

The dependence of the power requirement and, therefore, also of the fuel consumption on water depth, draught and speed is typified by so-called power-speed-profiles. These relationships apply to each vessel individually according to the vessel size and hull shape in each case. Ultimately, every constellation consisting of ship, draught and water depth has its own specific profile.

The extreme influence of water depth on the potential speed, that is, the power requirement is shown in Figure 1, using the Europe ship as an example: while a draught of 2.5 metres and a water depth of 5 metres permits a speed of 18 km/h, the achievable speed at half of this water depth and a draught of 2.00 metres is only 10 km/hour. The resulting effect on the cost structures is considerable.

These relationships will be analysed with the help of a model developed at the DST specifically for these problems. It will include the various cost items (materials, personnel, fuel) in the necessary complexity and will be able to depict appropriately the above mentioned dependencies between various water depths and their respective effects on speed, fuel consumption and costs for different vessels and draughts. The relevant parameters will be differentiated as follows:

- recording of different vessel types, taking into account the current development of the fleet structure
- variations in draught
- taking into consideration varying water depths, both in a stretch of waterway and over a period of time (annual hydrograph) and in the form of various discharge scenarios
- recording of load variants for bulk cargo and containers
- taking account of different transport relations.

3 Cost Structures

In the context of the previous work, the first cost calculations were carried out, along with the development of the model. The illustration in Fig. 2 shows the water levels for the years 2002 and 2003 (referring to Bingen/Oestrich) and the cost structures for a bulk cargo transport by GMS (large Rhine motor vessel) on the relation

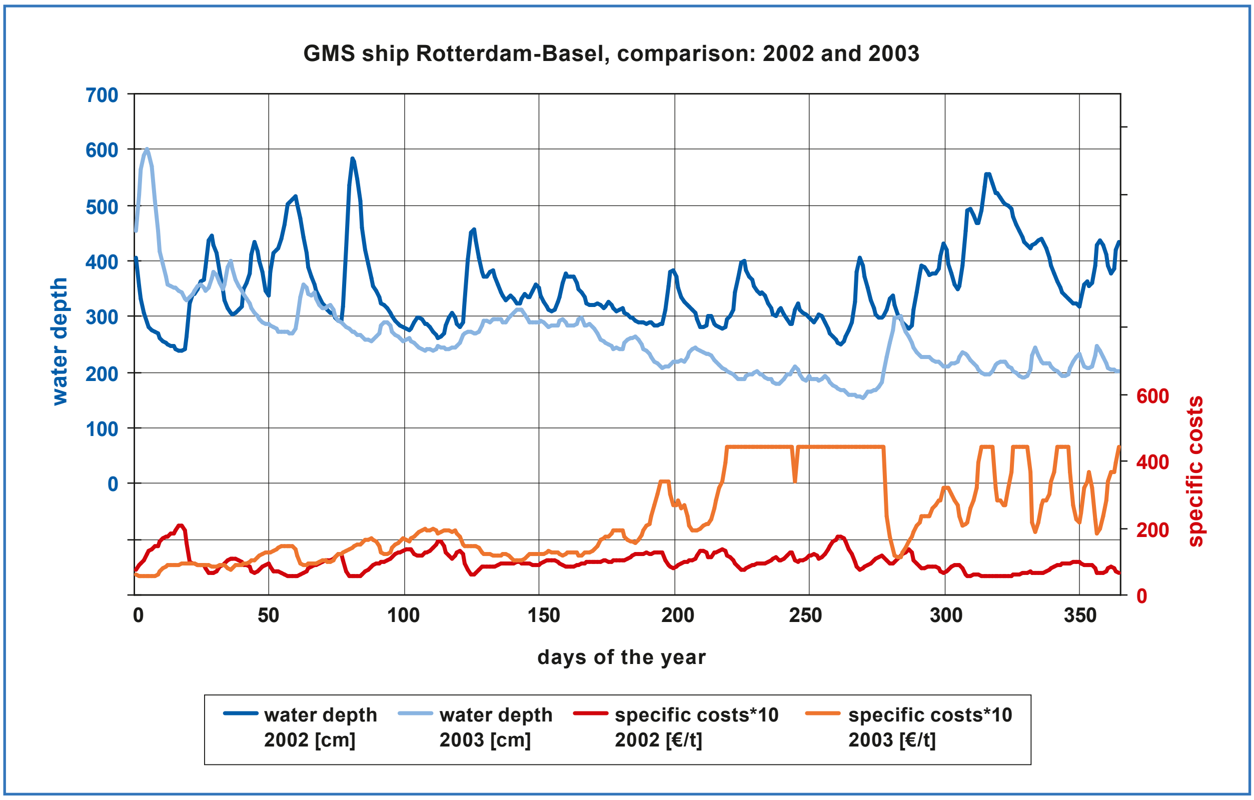

Fig. 2: Water depths 2002 and 2003 (referring to Bingen/Oestrich) and example of cost structures for vessel type GMS (bulk transport, relation Rotterdam–Basel)

Rotterdam-Basel. Whereas in the year 2002 there were almost no extreme low water situations, events of this kind were recorded in the year 2003, especially in the third quarter and, to some extent, in the fourth quarter. When a comparison is made of the water depths and the specific costs (costs per transport unit, €/t), it becomes apparent that the graphs for costs virtually mirror the graphs for water levels: at high water levels the specific costs were low and, exactly the opposite, at low water levels, the specific costs were high.

The disproportionately high increase in costs during the extreme low water phases of the year 2003 is particularly striking. The reasons for this are, on the one hand, the low speed that resulted in this period and, as a consequence, the longer roundtrip times which – in relation to one turnover – lead to higher personnel and fixed costs. On the other hand, it should be considered that when water levels decrease, the vessel can no longer be fully loaded, and as water depths continue to fall, the loading capacity is also diminished. The increasing overall costs must then be divided among a decreasing number of transport units, which is reflected in the disproportionately high specific costs during periods with extremely low water depths. During extreme low water periods, such as those of the year 2003, the GMS can no longer be used for relations on the Upper Rhine; this is shown in a simplified form in Fig. 2 as an upper limit in costs.

4 Summary and Looking to the Future

With the help of the cost model that has been developed, a more sophisticated depiction of the cost structures for inland vessel transport under various boundary conditions will be possible. Above all, the impact of different water depths on different vessel types can be determined, both on the level of individual years, as well as in the form of time sequences over many years. This will permit conclusions to be drawn on the relative advantages of individual vessel types in varying discharge scenarios. On this basis, the impact on costs of possible changes in climate or in discharge can be demonstrated for inland navigation in the Rhine region.

By taking into account the various transport relations, the transport volumes which can be transported or not transported in certain discharge scenarios, and the required fleet structure, can then be determined. By including the transport flows, conclusions can be drawn regarding the resulting impact on capacity.

Finally, courses of action, including the impact of measures, will be analysed. Besides investment measures (ship construction) for the inland fleet, there are also operative measures for inland navigation (operating mode) and changes of logistics concepts (on this topic, see also the contribution by Scholten and Rothstein in this volume)

Critical Influencing Variables for the Economic Sector Dependent on Bulk Goods

Anja Scholten (University of Würzburg) & Benno Rothstein (HFR)

1 Introduction

In the scope of the KLIWAS project No. 4.01, "Hydrology and Inland Navigation", the extent to which bulk cargo dependent industries along the Rhine are affected by low water will be analysed. This study focuses on the restrictions in inland navigation due to low water levels and resulting bottlenecks in the transport system.

In the analyses that are shown, the results are intermediate results based above all on the first answers to a survey of companies; these results may change in the further course of the project, as the survey is expanded.

2 Research Approach

In most economic models, specific data for certain sectors or businesses regarding the impact of low water and the courses of action of businesses during low water periods ("adaptation measures"), are not taken into account. The focus of this sub-project therefore lies, on the one hand, on the creation of a reliable data base related to the impact of low water periods on businesses and possible courses of action. On the other hand, this data base will be used to identify possible adaptation measures and, as required, to refine and, finally, evaluate them.

3 Survey Method

In order to survey the impact of low water on bulk cargo dependent industries in as much detail as possible, a questionnaire was developed including both general company data, such as the number of employees, and questions about preferred vessel size, storage capacity and perception of the degree of impact. Simultaneously, conversations at specialist level were held with key people from the various fields affected. The experts who were consulted included representatives from the affected economic sector, inland navigation, ports, stakeholder associations and science.

In order to include all large forwarding businesses on the Rhine in the survey as far as possible, the selection of the participating companies was carried out as follows: based on the data of the Federal Statistical Office, DESTATIS, Rhine ports which had handled more than 2 million tonnes in 2005 were identified, which yielded a selection of 14 ports (Destatis 2006). For each port, the three types of goods which were most frequently handled were considered. These, in turn, were assigned to the local industrial sectors and the largest companies which utilise these goods. Next, the companies were contacted by e-mail or telephone. The actual survey was then conducted either on-site, by post or by telephone. In addition, the questionnaire was put on the internet and publicised through the newsletter of the ShortSeaShipping Inland Waterway Promotion Center (SPC) (cf. Fig. 1). At present, the data acquired in the survey is being analysed qualitatively and quantitatively.

4 Sensitivity of the Economy to Low Water and Climate

Based on the expert talks and the company survey, a pattern of the mechanisms for dealing with the effects of low water periods on industries depicted in Fig. 2 could be reconstructed: as a result of lower water levels (and the resulting lack of depth in the navigation channel), the transport capacity of inland vessels is reduced; the degree of impairment also depends on factors such as ship type (cf. contribution by Holtmann & Bialonski). While the transport *capacity* of the individual inland navigation vessels is reduced, the transport *demand* of the businesses remains essentially the same. In order to meet their obligations, the companies are forced to use additional vessels. However, as there is only a relatively small volume of free shipping capac-

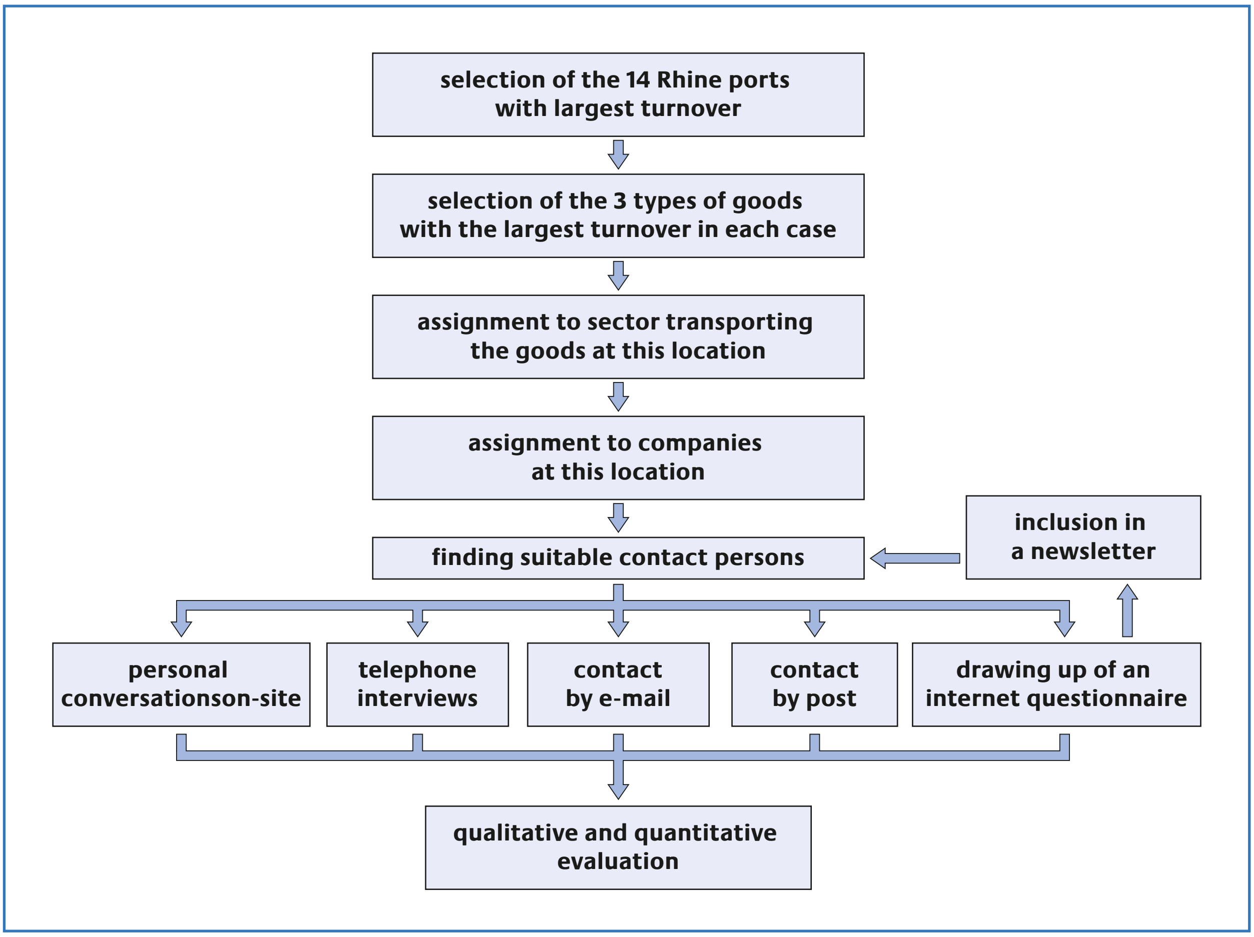

Fig. 1: Procedure for survey of companies

ity, the increasing demand and the mandatory low flow surcharges increase transport costs for the companies.

The available (free) shipping capacity is not sufficient to meet the transport requirements of the companies at all times. To compensate this, in some cases companies transfer some of their volume to other modes of transport, such as trains or trucks, depending on the available infrastructure. In the past, however, these only had limited availability (BAG [Federal Office for Goods Transport], 2007). In other instances, the companies fall back on their (often limited) stocks in order to keep production running. The restrictions on transport described above sometimes lead to the depletion of stocks of raw materials and/or to warehouses filled with finished products, depending on the available storage capacitiy. In the worst case, supply bottlenecks occur which can ultimately lead to a shutdown of production.

In the context of the company survey, the companies were requested to state the water level at which difficulties with transport occur, too. They usually referred to the local gauge and the gauge levels frequently corresponded to the limits for the low flow surcharges. It appears that companies along the Upper Rhine are only affected by lower water levels than those at the Lower

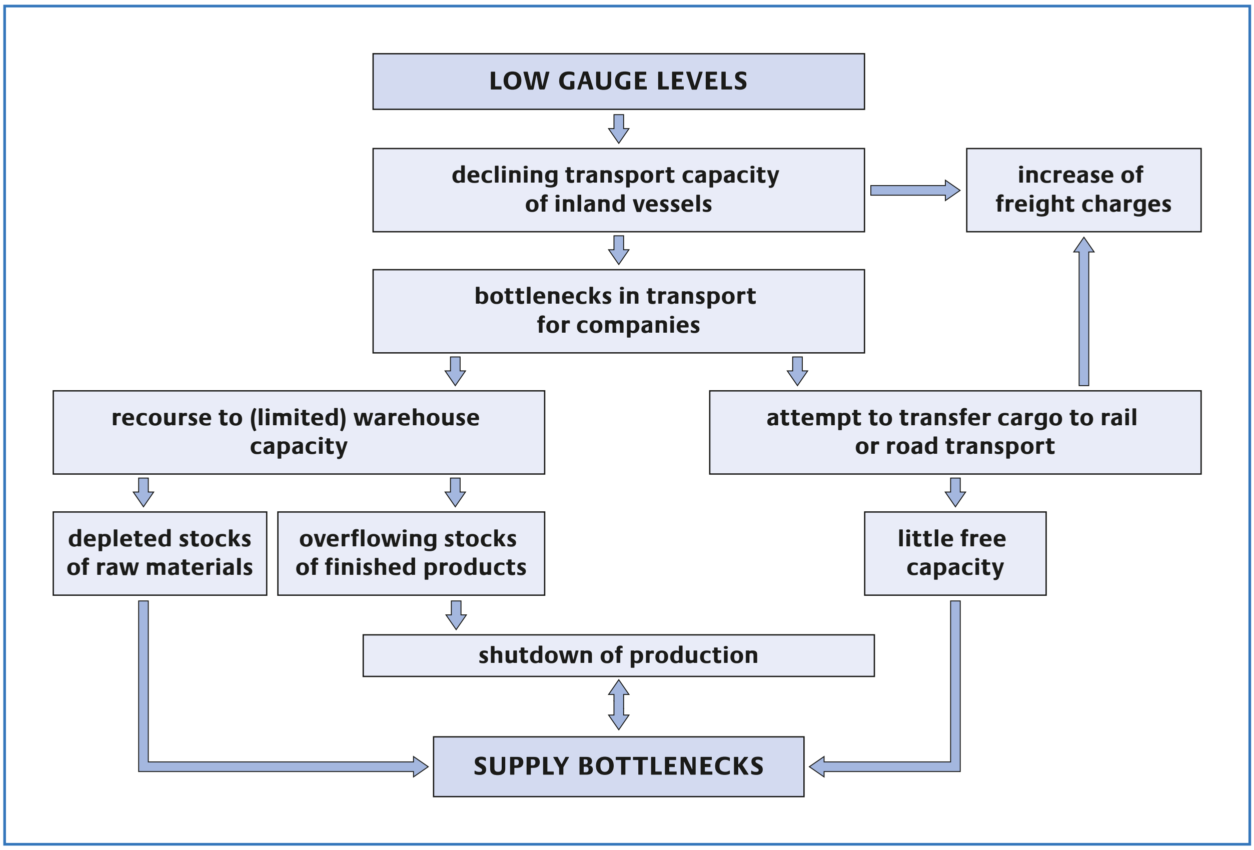

Fig. 2: Impact of low water on companies (source: own depiction based on company survey and conversations with specialists)

Rhine because, compared with companies on the Lower Rhine, they tend to use smaller vessels and pushing units.

With a reduction of the navigation channel depths, the potential carrying capacity of ships is also diminished. Accordingly, the critical parameter of ship capacity is distinguished by the fact that it dependends directly on the water level and the navigation channel depth (cf. contribution by HOLTMANN & BIALONSKI). This means that in some instances the companies require twice as many ships as they would need to transport the same cargo in optimum water conditions.

Transport costs also rise with the number of ships required. Besides the low flow surcharge which must be paid, the costs for the companies are caused principally by the increase in demand for available ship capacity that has been mentioned earlier. According to JONKEREN et al. (2007), the expenses per ship for one transport journey remain approximately the same regardless of how much a ship is able to transport. Thus, freight charges during low water periods can be the same for half empty ships, as would otherwise arise for fully laden inland navigation vessels.

In recent years, many businesses have introduced "just-in-time" procedures to reduce their costs for storage of raw materials, as well as intermediate and finished products (PROGTRANS 2007). An initial survey of companies shows that around one third of the companies questioned can maintain production for only one or two days without transport facilities, and another third has storage capacity for between 7 and 14 days. Larger storage capacities were found mainly in the energy industry, the coal and steel industry and at producers of construction materials, while the chemical industry and producers of (semi-)finished products have lower storage capacities.

Many companies are willing to transfer their cargo to smaller or more vessels, to trains or trucks, during low water periods. However, at normal water levels the use of new, small vessels makes little economic sense, which is why relatively few small ships are available (BAG 2001). Furthermore, rail and road freight traffic has only limited free capacities, es well – especially on major transport axes – meaning that the volume that can be transferred here is also restricted. In some cases, there are already bottlenecks in these modes of transport at rail and road hubs and in the availability of wagons, engine drivers and diesel units/locomotives (BAG 2007). Furthermore, 34 freight wagons (à 40 tonnes) or 57 trucks (à 24 tonnes) are required to replace one ship with a load capacity of 1358 tonnes.

5 Summary / Looking to the Future

To summarise, it can be said that almost all the companies questioned in the survey had already experienced transport problems caused by extreme events (e.g., storms, heat, low water or floods) and are expecting an increase in this kind of hindrance as a result of climate change. Companies with an affinity to bulk goods are affected by low water in matters such as security of supply and by rising transport costs. Low water causes companies to transfer transport to rail and road, although these possibilities are very limited.

The company survey will be completed and further analysed in the coming months. In addition, a survey of shipping companies (ship owning companies and owner-operators of ships) will be continued and – in cooperation with the DST – the future transport requirement will be analysed in the light of the expected fleet capacity. On the basis of these results, (possible) adaptation measures for companies and inland shippers will be investigated and assessed (also in cooperation with the DST).

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B2 Climate Projections and Discharge Scenarios for the Rhine

Hydrometeorological and Hydrological Developments of the Rhine in the Past 100 Years: Discharge Regime and Extremes

Jörg Uwe Belz (BfG) & Annegret Gratzki (DWD)

1 Extreme Low Water Events During the 20th Century

As well as fulfilling other important socio-economic and ecological functions, the Rhine and its large tributaries form the most important waterway system in Europe. For this reason, knowledge and understanding of discharge development and the processes which control discharge are of eminent importance; in terms of transport economics, this is particularly true in regard to extremes of low water, as these restrict navigation. The study "The Discharge Regime of the Rhine and its Tributaries in the 20th Century – Analysis, Changes, Trends" (*Das Abflussregime des Rheins und seiner Nebenflüsse im 20. Jahrhundert – Analyse, Veränderungen, Trends*) which was carried out on behalf on the International Commission for the Hydrology of the Rhine Basin (CHR) (Belz et al., 2007) has dealt with this set of topics in detail.

The Cologne gauge lies on the Lower Rhine, the section of the river with the highest volume of traffic. If we consider developments of extreme low water events using the NM7Q parameters (NM7Q describes the lowest discharge rate averaged over 7 days within a reference time period), then we see in Fig. 1a a rising trend in the general tendency of the curve of the running averaging as well as in the straight trend line. For low water events, this always means mitigation, in the course of the century, of somewhere in the region of 6%. Statistically, this change cannot be described as a significant trend, but only as an unverified tendency. If a distinction is made in the seasons (Figs. 1b and 1c), the development is reversed, with a tendency to a decrease in discharge in the summer months and, in winter, the opposite, with an increase (even as a verified trend with a level of significance of 95 %).

A similar development, but with a more distinct character in each case, took place in the Upper Rhine (example gauge: Maxau, Fig. 2a–2c). With reference to years, a trend-significant NQ increase of not less than about 124 m³/s occurred in the 20th century; this represents an increase of around 22 %. It is striking that the summer NM7Q values here are noticeably higher than the winter values. Because this is a statistical study of extreme low water events, the winter half-years therefore in principle also influence the annual random checks. In regard to the development over the whole century, the summer low water events decrease from a high level, whereas the winter low water events increase from a level that is already low.

2 Development of the Discharge Regime and the Processes that Control it

The basic relationships become apparent when the development of the discharge regime is first of all considered. The discharge regime reflects the water balance in its temporal changes and is the result of the interaction of all factors which determine the discharge for a specific catchment area under consideration. Discharge regimes look at the annual course of flow conditions with the occurrence and duration of high and low water periods, extreme high water and low water events over a relatively long observation period and the frequency distribution of the characteristic hydrological values (BMU 2003).

The analysis of discharge regimes in their various characteristics is commonly carried out according to the method developed by the French hydrologist Pardé (Pardé 1947). This method uses standardised monthly discharge coefficients. In this way, the succession of months with stronger or weaker discharge rates is

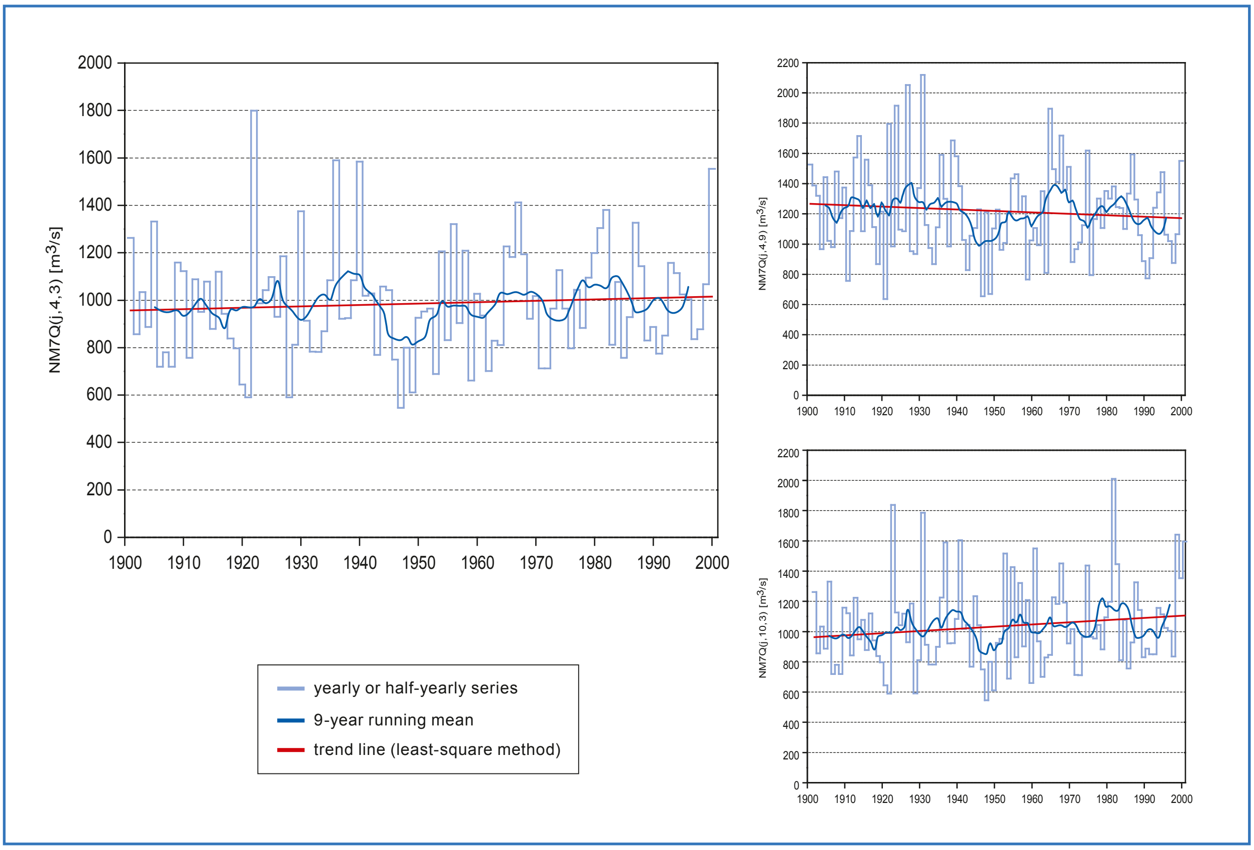

Fig. 1: Cologne gauge: NM7Q extreme values in 20th century observed over the whole year (Fig. 1a, left) and in reference to the summer half-year (Fig. 1b, right, top) and winter half-year (Fig. 1c, right, bottom)

identified by standardising them in exact relationship to one another without distortion caused by differing magnitudes of the bodies of water. Various typical patterns emerge in the intra-annual discharge hydrograph, which represent the various regimes. In the Rhine region, the most important of these are (cf. Fig. 3):

- nival regime (red; example: Ilanz), with peak discharge in the summer due to snowmelt and a discharge minimum in winter because of the binding of water in the form of ice and snow ("Winter is low water time.")
- pluvial regime (blue; example: Trier), with peak discharge in rainy winters and a discharge minimum in the summer as a result of intensive evapotranspiration ("summer – or autumn – is low water time")
- mixed regime (yellow; example: Cologne), in which pluvial and nival elements mingle.

The old familiar Pardé procedure for calculating the development over a century was modified by dividing the period 1901-2000 into four sub-periods of 25 years each.

The results described in the context of the trend analysis NM7Q with their seasonal differentiations are initially confirmed here in the pluvial mixed regime (Lower Rhine, Cologne gauge cf. Fig. 4).

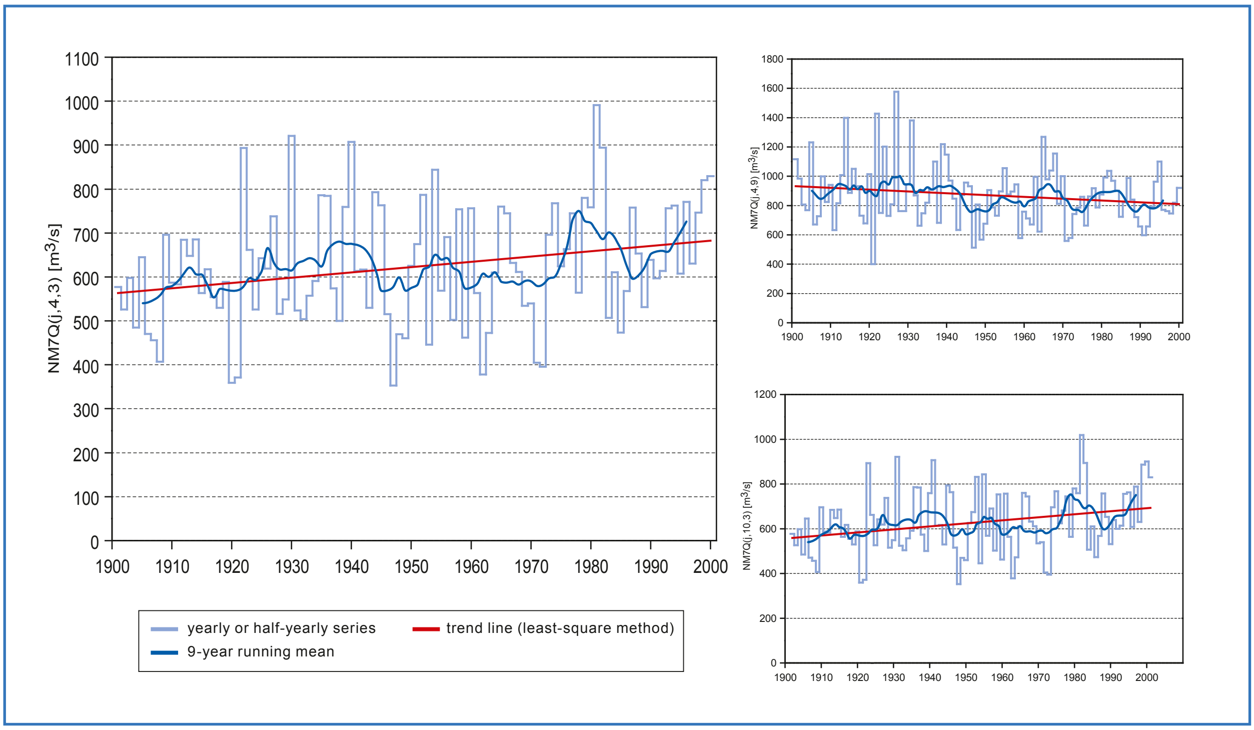

Fig. 2: Maxau gauge: NM7Q extreme values in 20th century observed over the whole year (Fig. 2a, left) and in reference to the summer half-year (Fig. 2b, right, top) and winter half-year (Fig. 2c, right, bottom)

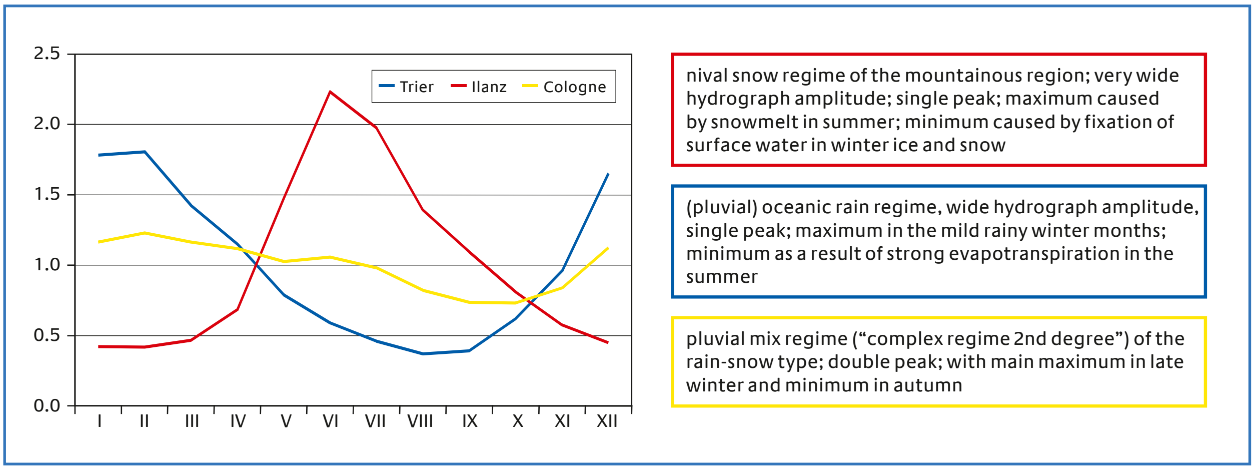

Fig. 3: The most important discharge regime types in the Rhine region in their intra-annual characteristics

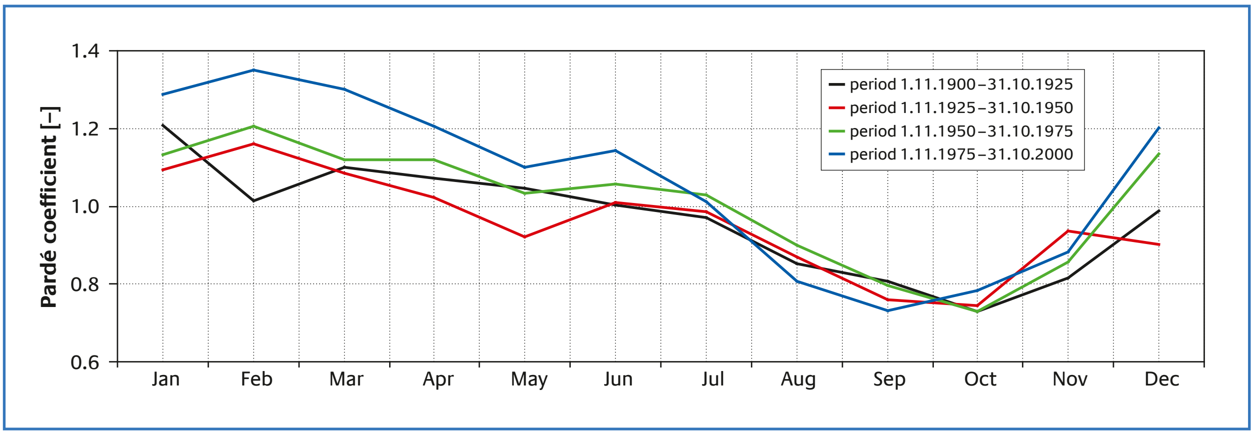

Fig. 4: Cologne / Lower Rhine gauge: change in discharge regime in the 20th century (standardisation reference: period 1901–2000)

Here the increase of the mean discharge during the 20th century amounts overall to around 240 m^3/s and can be traced principally to the winter season.

The main driving forces behind this are the increasing amounts of regional precipitation, the development of which, as shown in Fig. 5a on a decadal basis, is very uniform in the Rhine region during the 20th century, especially in the winter half-year; the exceptions are principally in the Alps and the foothills of the Alps (MGN_I and MGN_II). Adjacent to this, Fig. 5b shows the control process responsible for the increase in precipitation, also with reference to the winter half-year: the development of the continental scale weather patterns (GWL) which is characterised, on the whole, by an increase in wet patterns during the course of the century.

The development of the discharge regime in the southern Rhine region, which is subject to nival influence, depicted here in Fig. 6 using the example of the Upper Rhine gauge at Maxau, has different characteristics when compared to the Lower Rhine. Seen overall, there is a redistribution effect here: the summer months which already have high discharge levels are losing; the winter months, with low discharge and the typical, associated extreme low water situations are gaining. In the mean, this redistribution represents only a slight increase for the system as a whole.

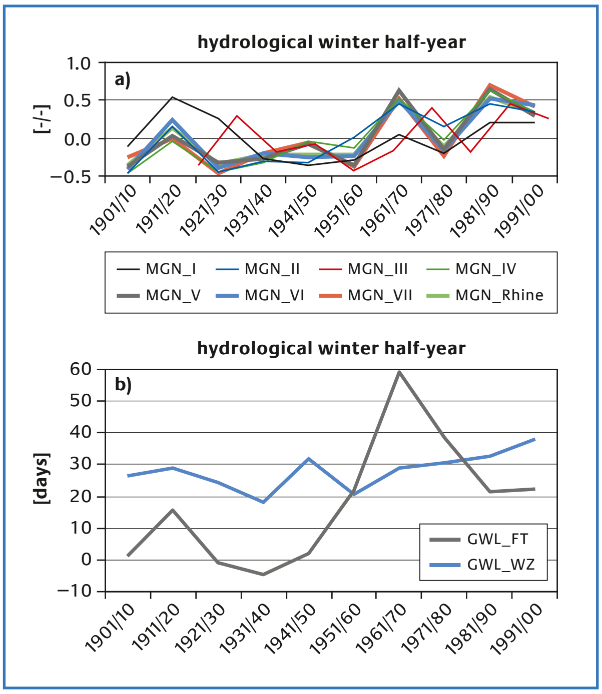

Fig. 5: Precipitation development and control processes in the Rhine region in the 20th century: top (Fig. 5a) regional precipitation of the various subcatchment areas (MGN) – standardised, seasonal decadal mean values (winter), bottom (Fig. 5b) development of continental scale weather patterns (= GWL) in the Rhine region (decadal mean, winter), GWL_FT: difference in days with wet and dry weather / GWL_WZ: number of days with continental scale weather pattern "west cyclonic"

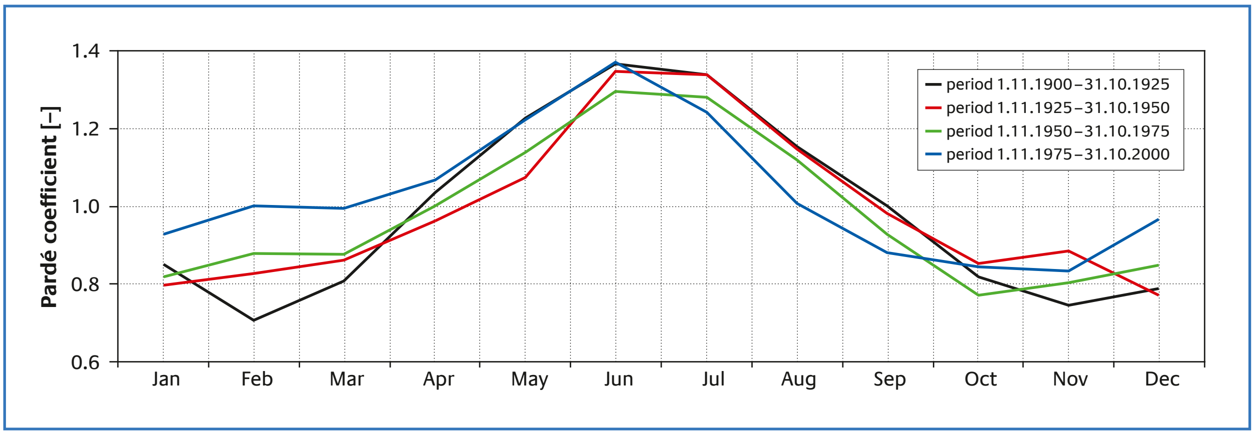

Fig. 6: Maxau gauge: change in discharge regime in the 20th century (standardisation reference: period 1901–2000)

The rising air temperatures over the course of the century are of major significance for this redistribution trend. A seasonally differentiated observation (Fig. 7) shows the largely uniform development for the entire Rhine region in winter, with a marked increase since the 1960s. The summer development, by contrast, is less uniform, but is still characterised by increase.

The most significant consequences of increasing air temperatures in the Alps and their foothills, as well as in the higher regions of the Jura, the Black Forest and the Vosges, is a change in the characteristics of the snow cover: there is more rainfall with direct impact on discharge; by comparison, less water is stored for the snow melt in spring and summer – the warm season, with its typically high discharge rates loses discharge, the winter season, typically with low discharge, has increasing discharge.

The large reservoirs in the Alpine region, almost all of which are used for producing energy and are therefore uniformly managed, have a similar effect. In the low-discharge winter period, additional water is required for constant turbine utilisation; in the summer, this can be acquired from the well-filled surface waters. As a result, there is also a redistribution of discharge from summer to winter, however, as a process of anthropogenic origin. When only the largest facilities, with a

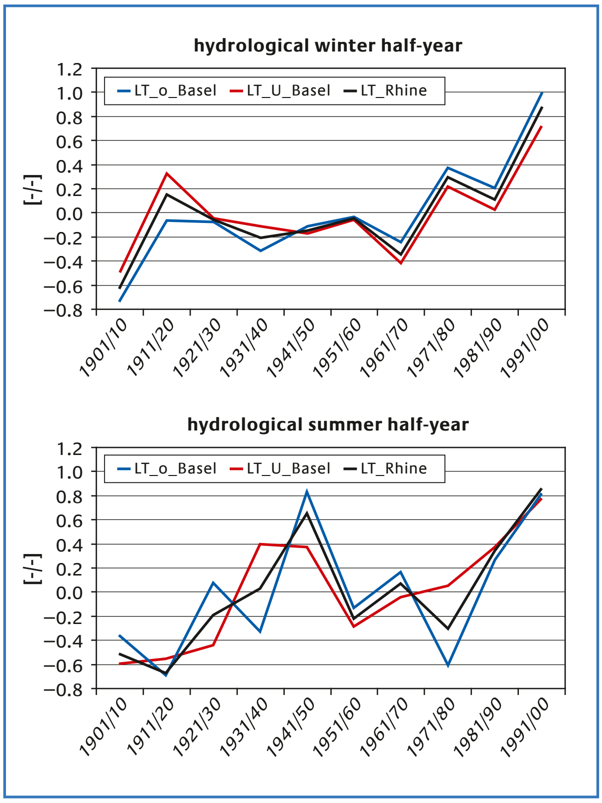

Fig. 7: Air temperature (LT) – standardised seasonal decadal mean values in the Rhine region and in the sub-regions upstream and downstream from Basel in the course of the 20th century

storage capacity of 0.3 hm³ and more, are considered, the volume of water storage that has been created in the Alps during the 20th century amounts to approximately 1.9 billion cubic metres. Expressed as an over-simplification, this means there is a seasonal redistribution at the Basel gauge of about 60 m³/s, that is, about 7% of the winter MQ (mean flow rate).

The processes shown here vary in their impact according to area. In the northern Rhine region, the very large volume of reservoir capacity that was also created in the 20th century (approx. 1.3 billion m³) does not have any influence as a redistribution force because the dams here are utilised differently and are subject to heterogeneous controlling factors. In the southern catchment area, the changes in continental-scale weather pattern characteristics are considerably less intensive, because there has been a simultaneous change in the direction of movement of these weather patterns from west-east, as was formerly the case, to south-west to north-east. Consequently, the rain shadow function of the Alps, the Jura, the Black Forest and the Vosges in reducing precipitation is reinforced and, in any case, in the mountainous regions with their more distinctly structured topography, small scale regional climates can already develop more easily.

3 Differences along the Course of the River Rhine

When differences in the Pardé monthly discharge coefficients are derived from a comparison of the first and last quarters of the 20th century, the relevant intra-

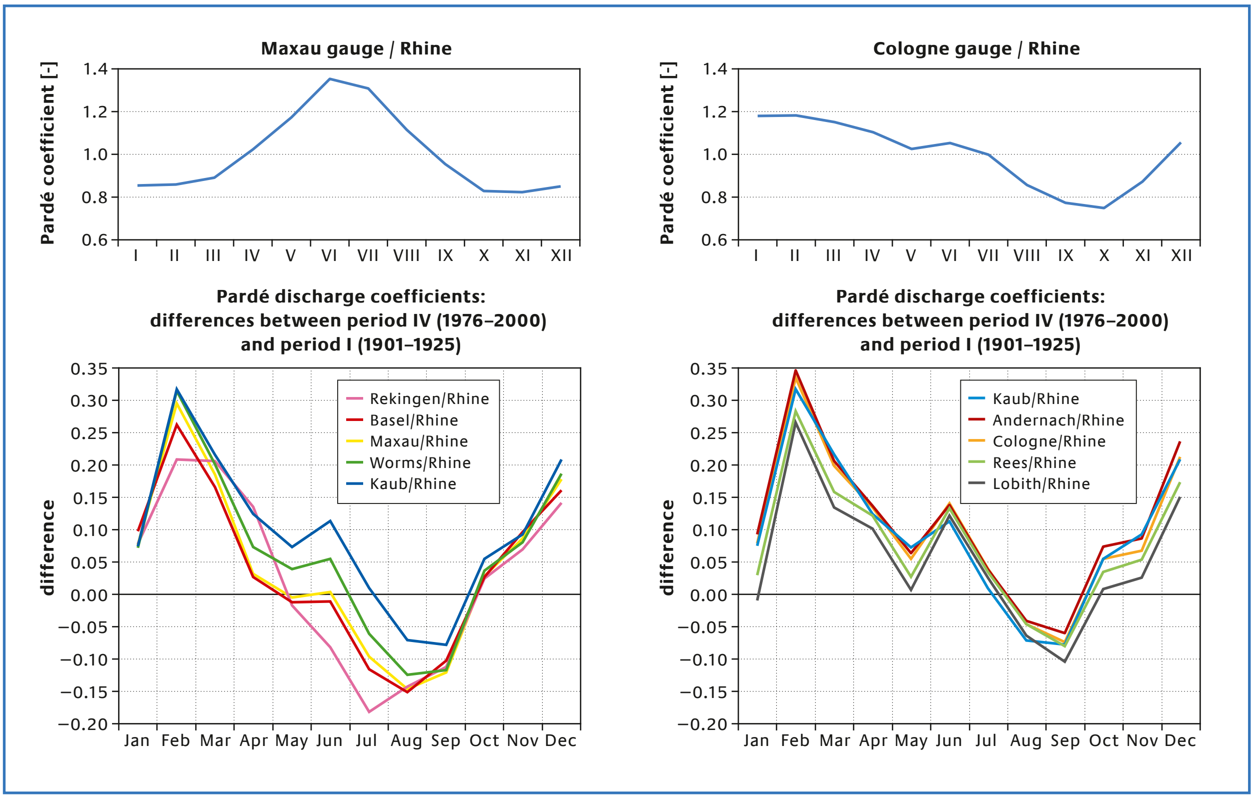

Fig. 8: Development of discharge regime in the 20th century along the longitudinal profile of the Rhine

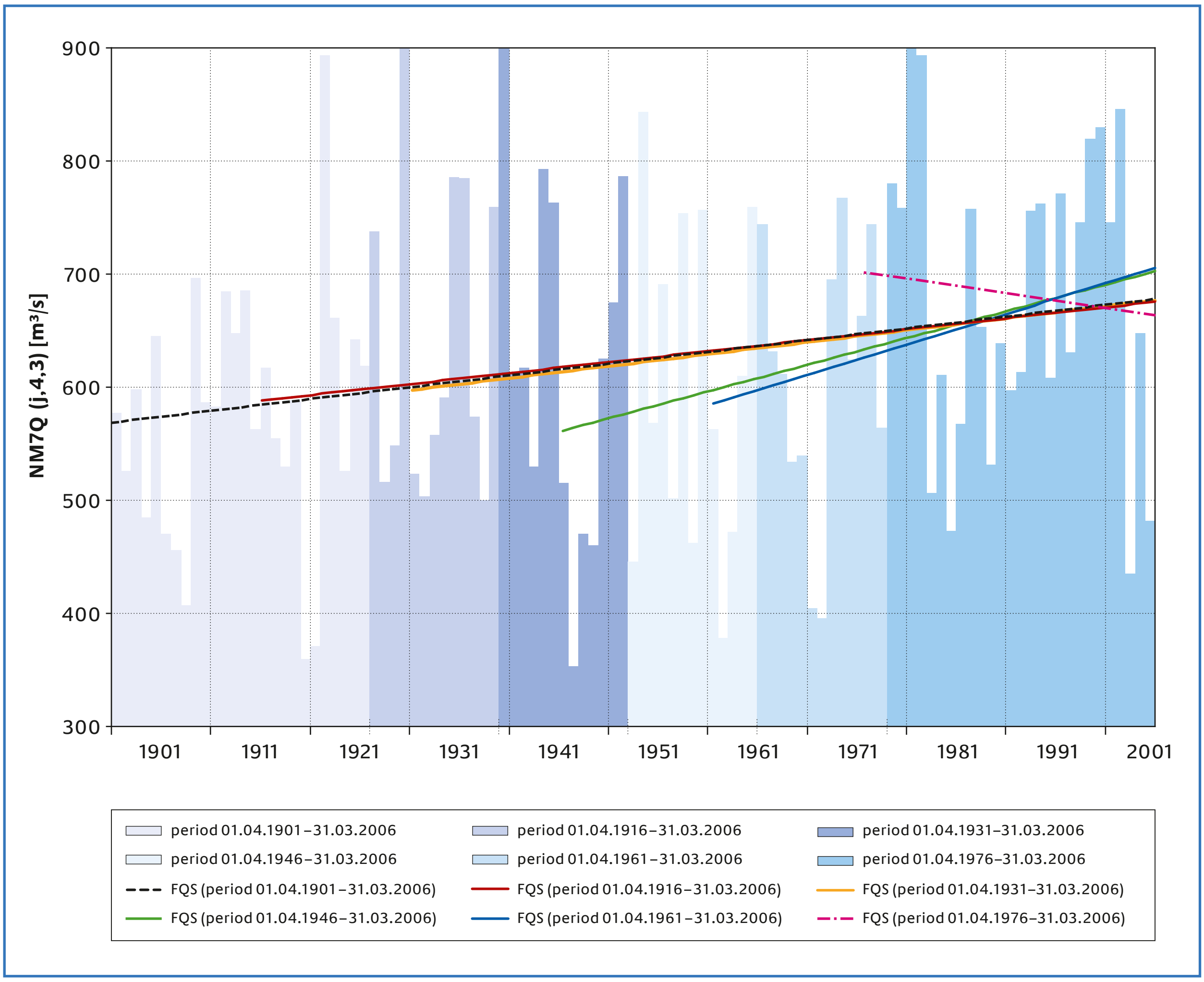

Fig. 9: Maxau gauge (Rhine): Low water extremes (NM7Q series of years) – trend analysis of differing periods of time (FQS trend line on the basis of the widely used method of least error squares)

annual differential hydrograph can be obtained. When viewed from a synoptic perspective of the differential hydrographs of various gauges over the longitudinal profile of the Rhine (Fig. 8), the consequences of the development during the century in the sub-regions, with their various characteristics, become apparent. With regard to the low water development, the dynamics of the century meant that in every area in which winter was a typical low water period there has been a noticeable increase in discharge and, thus, (now generally verified as a trend by the statistics) a mitigation of the low water extremes. On the contrary, in every area with typical low water months in late summer/early autumn there has been a slight tendency towards a reinforcement of extreme values, however with less statistical clarity and, therefore, in a way that cannot be confirmed as being significant. The transition area between the two basic types of the Rhine region, the southern, with stronger nival influence and the northern, with increasing pluvial influence lies approximately at the confluence of the Main with the Rhine.

4 Statistical Validation

The results of statistical analysis depend strongly on the underlying boundary conditions, such as base data, the time slot being studied and the methodology used. A trustworthy analysis of statistics is therefore particularly concerned with objectivity. This is achieved by validation of the results. In the case of the study that has been presented here (Belz et al., 2007, see there), this was carried out repeatedly and used exclusively robust, easy-to-reproduce methods of classical trend analysis (least-square) with the Mann-Kendall significance test, alongside analysis of the discharge regime, analysis of comprehensive and decadal mean values, jump analysis and various other homogeneity tests. The procedures were applied and evaluated parallel to one another and continually accompanied by argumentative, physical plausibility checks. The results presented are, as a rule, mutually support and confirmed.

A further, progressive trend analysis commissioned for the Upper and Lower Rhine goes in the same direction: in this progression, the entire 105-year period of the study from 1901 to 2005 is progressively reduced, in steps of 15 years (example: Maxau gauge, Fig. 9). The significant upwards trend which was shown for the hundred-year period is confirmed; the trend is persistent in direction and significance, even after time-slot modifications. One small exception can be identified: the most recent period from 1976 to 2005 shows contradictory (falling) tendencies; these are, however, not significant and conclusions cannot be drawn from them for statistical purposes. The progressive trend analysis that was carried out analogously for NM7Q at the Cologne gauge (no diagram) also supports the conclusions that have already been drawn, without the exception mentioned above of the period 1976–2005.

5 Summary / Looking to the Future

Major changes in the discharge regime have taken place in the Rhine region during the 20th century. In spite of the use of different analysis methods, the same result is found with overwhelming frequency: according to this, an increase in discharge in the winter months can be detected in most of the sub-regions in the course of a century; by contrast, in the summer season, discharge levels change only to a much smaller degree (and if so, then frequently with a vague tendency to fall). The changes in discharge can be traced back to climatic developments (increases in temperature and precipitation) and are reinforced by anthropogenic intervention, particularly the management of Alpine reservoirs.

This means a marked increase in discharge and, thus, mitigation in regard to extreme low water events for the southern Rhine region, where the winter half-year is generally the period with the lowest flow conditions in surface waters. North of the River Main (approximately the dividing line between North and South Germany) the months with the lowest gauge levels are late summer and autumn – here there is a non-directional, and in part, also, a slightly falling tendency in low water events. This slight aggravation of extreme low water events in the northern Rhine region is, however, so weak that it cannot be proved to be of any statistical significance.

In the low water range, the unclear signals from the south have been showing a contrary development since the 1970s (i.e. slight aggravation of the low water situation), although still at a high discharge level and, as yet, without any statistical significance. If nothing else, this reinforces the necessity of more detailed study of discharge behaviour now and in the future in the context of the KLIWAS project.

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Comparative Analyses of Regional Climate Models for the Present and Future Climate

Katharina Bülow (MPI-M), Daniela Jacob (MPI-M) & Lorenzo Tomassini (MPI-M)

1 Introduction

It is undisputed that the earth's climate has changed in recent decades, as can be seen from the numerous records of meteorological and hydrological services from all over the world. It will now be particularly interesting to discover how the global climate change could develop in different regions and what regional impact must be expected. For studies of this type, global and regional climate models have been developed which, along with various assumptions on the future development of greenhouse gases in the atmosphere, will calculate possible climatic developments during the next 100 years.

These computer models can be regarded as mathematical depictions of the earth system, as they describe the physical processes in the earth system numerically and calculate them as realistically as possible. In order to estimate the quality of the climate models, they are first used for calculations for periods in the past. For this, a period for which numerous global observations are available is generally to be preferred.

In order to describe future climate changes in the Rhine catchment area, numerous regional climate projections for the 21st century will be studied. These different regional climate projections were calculated with a large number of regional climate models – embedded in information from various global models. However, even when using various global and regional climate models it is still not possible to determine the whole spectrum of regional climate developments. Studies of possible regional climate changes must therefore include the analysis of uncertainties which occur in the climate system and in the methods used. Finally, ranges of possible changes in certain climate variables in specific regions should then be indicated.

We will now discuss these uncertainties and the options for dealing with them.

- Changes in climate depend essentially on the composition of the atmosphere and, consequently, on the future development of greenhouse gas emissions. Global and regional climate projections therefore take account of various artificially derived emissions developments, such as those proposed by the IPCC (SRES A1B, B1, A2).
- The non-linear character of the climate system can be seen, for example, in internal variability which can be computed by calculating several realisations of a climate scenario with a model. The internal variability of global and regional climate models has been investigated in detail in the EU ENSEMBLES project. This includes calculations with slightly modified initial and boundary conditions as well as calculations with slightly modified physical parameters. The internal variability for the global model system ECHAM5/MPIOM lies at around 0.5 K.
- In order to allow for differing climatic sensitivities of the various climate models, a comparison of many global or regional models is made, and a multi-model ensemble is produced for each emissions scenario (IPCC, 2007).
- For the analysis of percentage of uncertainty in the regional climate indicator, which is affected by the downscaling method, various dynamic and statistical methods are used to apply results from a global climate model to the regions. Work on this has also been carried out in the ENSEMBLES project.
- The range which can arise through the use of different regional, dynamic models was analysed for Europe in the EU project PRUDENCE (Jacob et al., 2007).

To summarise, it can be ascertained that the overall uncertainty is determined by many individual contributions. However, they are not simply added to one another, so that each contribution must be studied individually. Multi-model ensembles are just as essential for doing this as a large number of realisations of individual model chains, right to the climate impact model.

We will now demonstrate the first results of possible climate change for the Rhine catchment area. The proportion of global climate models in the range of the indicator of the regional climate projections will be examined, as well as that of the emissions scenarios. Initially, examples will be shown of a detailed validation of the regional climate models for present-day climate that were used.

2 Models and Parameters

Numerical regional climate models calculate dynamic and thermo-dynamic processes in the atmosphere on the basis of physical laws, in a way similar to weather forecasting models. Because of the spatial restriction to Europe, it is possible both to reduce the grid size and to improve the physics of the models. Regional climate models are embedded in the result fields of global climate models, that is, they receive the meteorological drive and boundary conditions from the global model, while within their own model region, they can use a topography with higher resolution and their more sophisticated physical parameterisations for simulations of features such as cloud formation.

Two different areas are being studied in this work. On the one hand, the regional climate models (a total of 14 regional climate models) were driven with ERA 40 data from the ECMWF (Uppala et al., 2005) for the period 1961–2000 and compared with observations in order to determine the quality and/or the uncertainty of the models in calculating present-day climate conditions and in order to be able to define a range for present-day climate. On the other hand, climate projections for diverse emissions scenarios (IPCC, 2007) are available from seven globally coupled climate models. The results of a global climate model were used as the driver for one or more regional climate models with a horizontal resolution of 25 kilometres. Around 14 regional climate projections for Europe for the 21st century are to be examined.

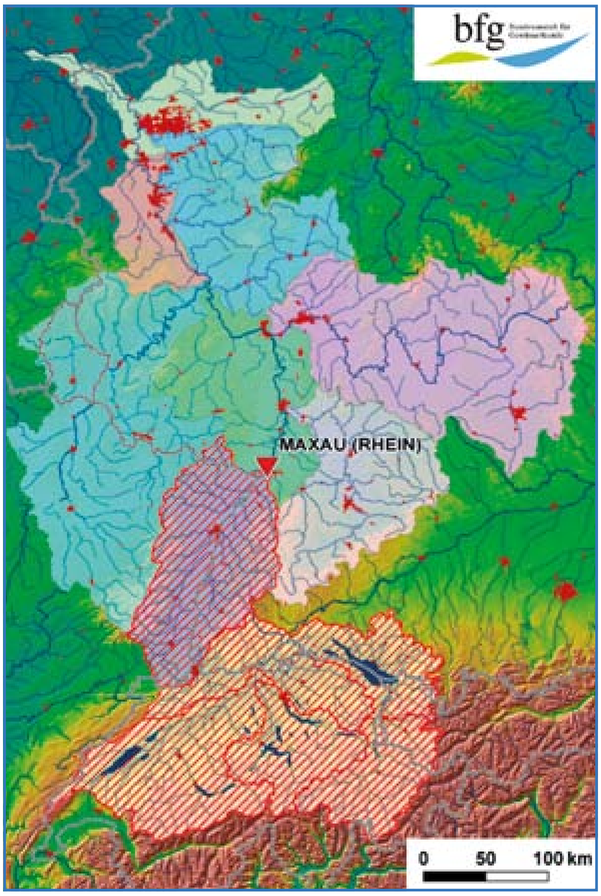

Fig. 1: Rhine basin with subcatchment areas and the Maxau gauge

The range of the regional climate projections will be evaluated using a value catalogue which has been specially designed for low water situations of the Rhine.

The time series of the regional climate models driven with ERA40 data for the period 1961–2000 and the time series of the regional climate projections for the period 1950 to 2050 (in some cases, extended to 2100) were calculated in the context of the EU ENSEMBLES project (Hewitt and Griggs, 2004) and will be supplemented by additional climate projections from the regional climate models CLM and REMO. The observation data set (Haylock et al., 2007) was also made available from the EU project ENSEMBLES. The hydrological parameters for the mean values of the subcatchment areas of the Rhine will be calculated. The catchment area mean of the Alpine section of the Rhine basin, including the Upper Rhine as far as the Maxau gauge, is depicted in Fig. 1 as an example of future climate projections.

3 Comparative Analysis of Regional Climate Models for the Period 1961–2000

In order to determine the quality of the regional climate models, they were embedded in so-called reanalyses for the period 1961–2000 and the results were compared with observation data. Reanalyses are the result of model calculations in which measured data flows into the model, so that the model calculation as closely as possible approaches the observed reality. Reanalyses are thus a kind of combination of observation and model calculation and are very close to reality in regions for which a high density of measured data is available. In regions with little data, the model influence predominates. For this reason, reanalyses may deviate from the historical reality if the amount of observation data is small. It can, however, be assumed that they reflect meteorological events of the past very well. At present they are the best product for depicting weather sequences in the past.

The observations used for validation purposes for Europe lie on a grid with a horizontal resolution of 25 kilometres.

3.1 Changes in Temperature

Hydrological Half-Years

The observed temperature changes for the hydrological summer months from 1961 to 2000 are largely underestimated by the climate models; this is true for all the subcatchment areas (Fig. 2). Only one model appears to assign the magnitude of the observed changes appropriately in all catchment areas. The observed changes for the hydrological winter months (not illustrated) are larger and spatially more homogeneous than those

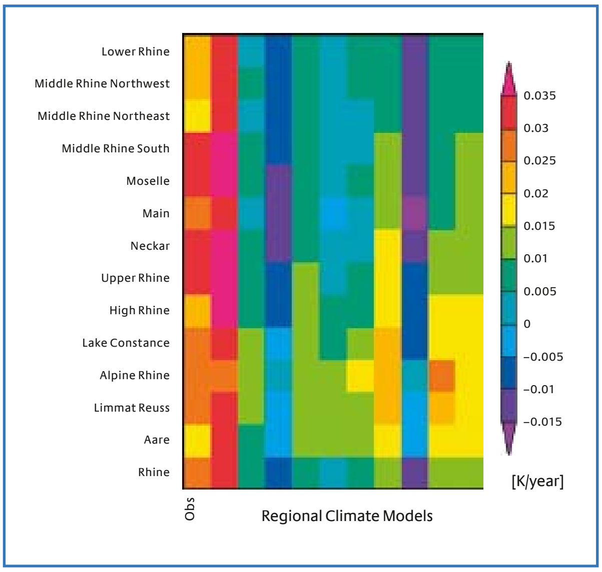

Fig. 2 Temperature changes in the hydrological summer months over the period 1961–2000 for all subcatchment areas, all regional climate models and the observations

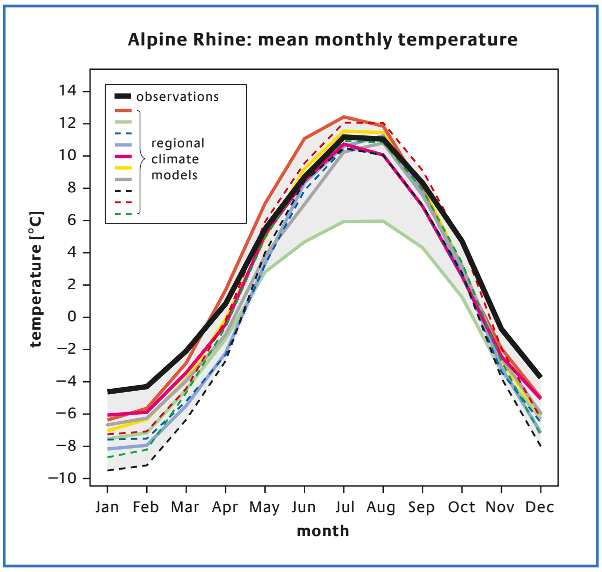

Fig. 3: Mean monthly temperature over the years 1961 to 2000 for the catchment area Alpine Rhine, the observations and all regional climate models

for the hydrological summer months. They are not as distinctly underestimated by the climate models as the changes for the summer months. The changes in temperature from 1961 to 2000 are statistically significant. The underestimation of the changes by the models requires further analysis.

Monthly Means

The monthly mean temperatures are underestimated by all the regional models, especially in the winter, as can be seen here in the example of the subcatchment area of the Alpine Rhine (Fig.3). The underestimation of the temperature in the Alpine zone of the Rhine catchment area is very distinct, with differences of up to 5 °C for individual models. The summer temperatures, by contrast, are calculated much more realistically. Only one model showed an underestimation of more than 5 °C.

3.2 Changes in Precipitation

Unlike temperature, the changes in precipitation over the period from 1961 to 2000 are not significant, either in the observations or in the regional climate models.

Monthly Totals

The mean monthly precipitation amounts are usually overestimated by the models in comparison with the observation data (Fig. 4), as depicted here using the example of the catchment area of the River Main. However, it should be noted that this is an observation data record that has not been corrected, and systematic errors in the measurement of the precipitation have not been taken into account. These systematic errors in measurement of precipitation often lead to values in uncorrected observation data records that are too low. However, it is unlikely that the entire overestimation can be explained only by the measurement errors. It is caused partly by inadequacies in the models.

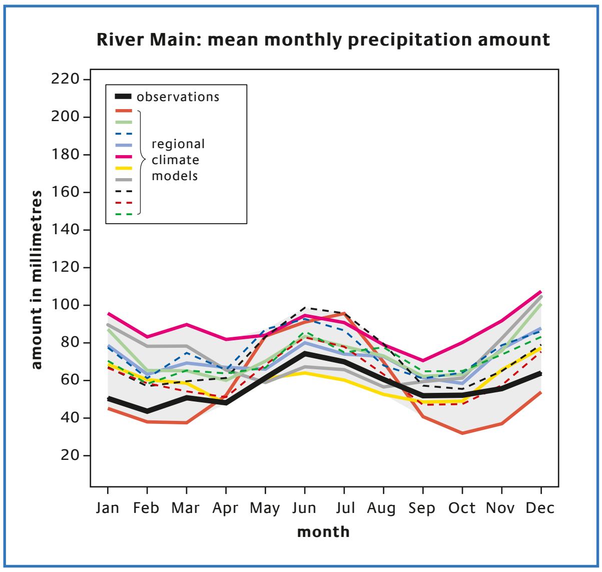

Fig. 4: Mean monthly precipitation amounts over the years 1961 to 2000 for the catchment area of the River Main, the observations and all regional climate models

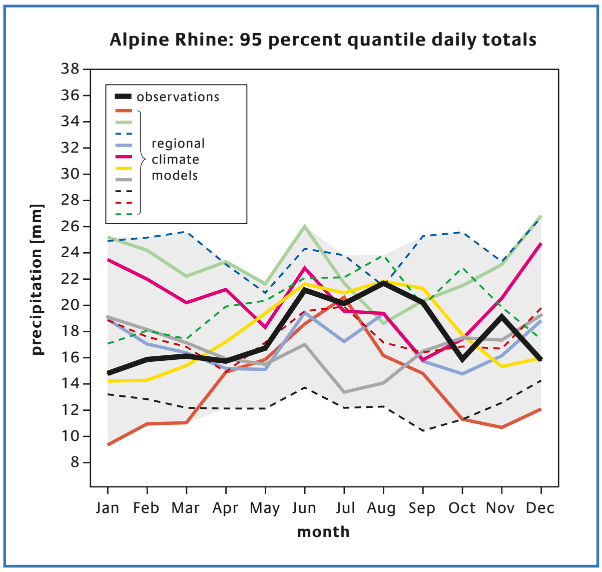

Fig. 5: The 95 percent quantile of the daily precipitation amounts for the catchment area Alpine Rhine, the observations and all regional climate models

The range of results of the regional climate models for the mean monthly precipitation amounts of 50 mm/month is high; however, the observed annual hydrograph is represented by most of the regional models in a very similar way to actual observations.

The 95 % quantile in the daily precipitation amounts can be regarded as a standard for very heavy precipitation. The range of data calculated from the results of the regional models is very wide. The deviation from the observation data can amount to up to 10 mm (Fig. 5).

How well the regional climate models simulate the days with little precipitation can be read off in the histogram of the daily amounts (Fig. 6). The distributions of daily precipitation amounts of the summer months in the catchment area of the Alpine Rhine are shown for the observation data and for three selected regional climate models. Although the climate models underestimate the number of days without any precipitation, they more than adequately reproduce the total number of dry days (that is, days with less than 1 mm precipitation).

In other respects, the distribution of the amounts for individual days in the regional climate models matches the observations quite well: the maximum periods of dry days (Fig. 7) in the summer also shows a good correlation, although in the low mountain ranges of the Rhine basin, the length of the periods was slightly underestimated. It should be noted that since the maximum period of dry days was determined for the entire period of forty years (1961–2000), these are not very robust statistics. Differences of a few days between observations and models can be considered acceptable.

4 Preliminary Results of the Regional Climate Projections for the 21st Century

The regional mean temperatures and precipitation totals for the Rhine catchment area as far as the Maxau gauge were calculated and evaluated for the years from 1950 to 2100 in regional climate projections for the SRES scenario A1B. The regional climate projections differ as to which regional climate model was used or

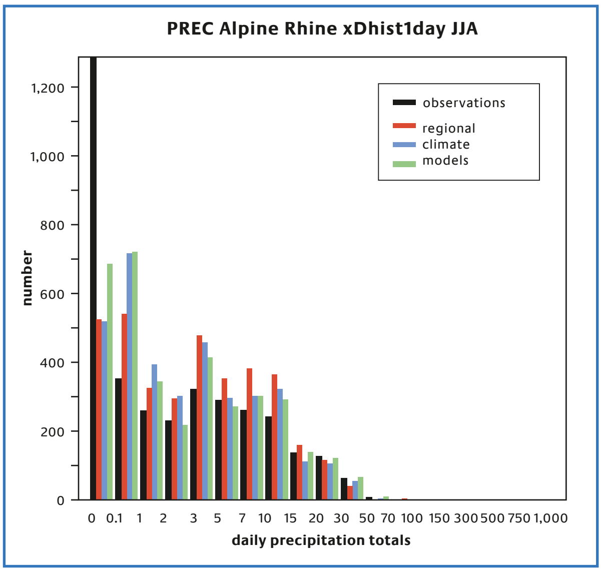

Fig. 6: Histogram of the daily precipitation amounts of the summer months for the catchment area Alpine Rhine, the observation data and three selected regional climate models.

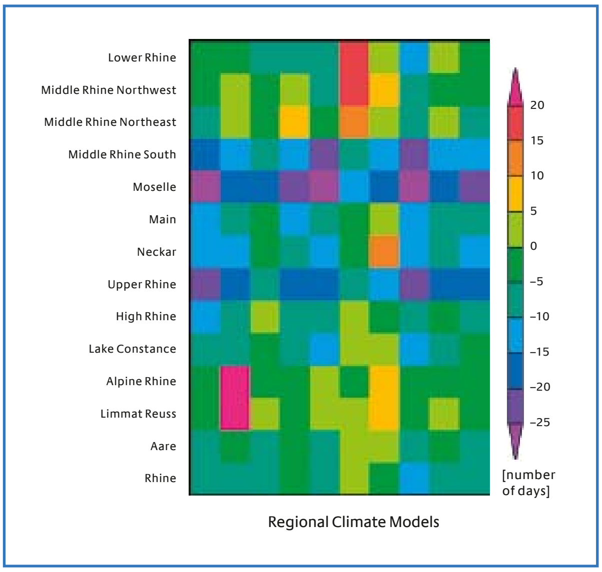

Fig. 7: Maximum period of dry days in the summer over the entire period 1961–2000 for all catchment areas and all regional climate models. The difference between the models and the observations is shown.

which global model was the driver (ECHAM5 or HadCM). Among them are the results of a regional climate model which was driven with various realisations of ECHAM5.

4.1 Changes in Temperature

The global climate projections of the different global models which were used in ENSEMBLES indicate a range of 1.5 °C for the temperature changes for the scenario A1B at the end of the 21st century. The global temperature change also shows an additional, slight increase in the range when compared with the year 2000 (ENSEMBLES Newsletter, 2009).

The range of the 30-year monthly temperature mean from six regional climate projections lies at around 4 °C in spring and summer (Fig. 8). In winter, the range is markedly smaller, at 2 °C. The range of all regional projections does not alter with time. By 2070–2099, however, the temperature maximum shifts from June to July, regardless of which global driver is used. Overall, the regional climate projections demonstrate a wide range, from 2–4 °C, while the lower and upper limits of the range for the individual months originate from the results of different regional climate models.

The decadal mean values demonstrate a clear increase in temperatures in winter and summer. The degree of warming is similar in almost all the simulations and indicates similar climatic sensitivities of the model chains used. The range in summer (Fig. 9) is significantly larger than in winter (not illustrated).

4.2 Changes in Precipitation

The results of the 30-year mean monthly precipitation amounts show a markedly smaller range in winter when compared with the rest of the year (Fig. 10). The decrease in precipitation in all regional projections in July, August and September for the period 2070–2099 in comparison with the two preceding mean 30-year precipitation totals is striking.

The spread of the decadal precipitation mean values is also distinctly lower in winter than in summer. In the

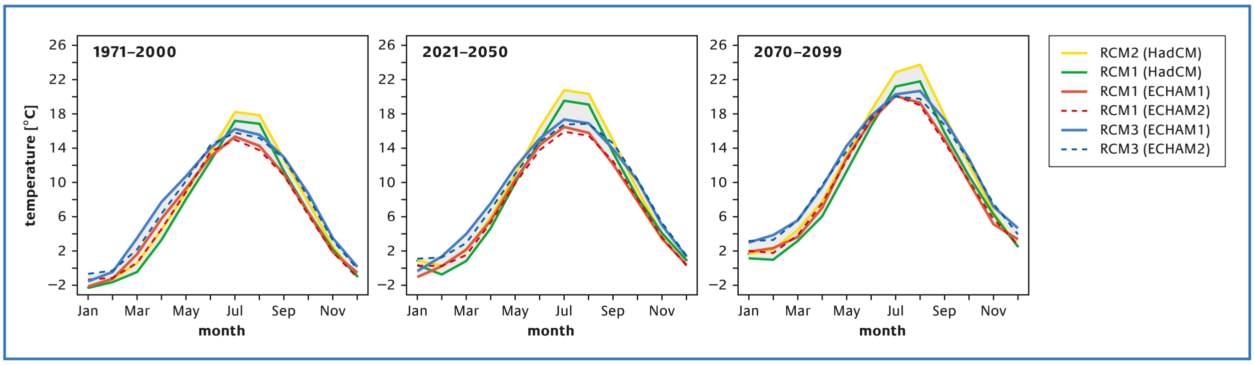

Fig. 8: Maxau: 30-year regional mean for monthly temperatures [°C] for the periods 1971–2000, 2021–2050, 2070–2099 (from left to right), calculated by 3 regional climate models, driven by 2 global climate models, for SRES A1B

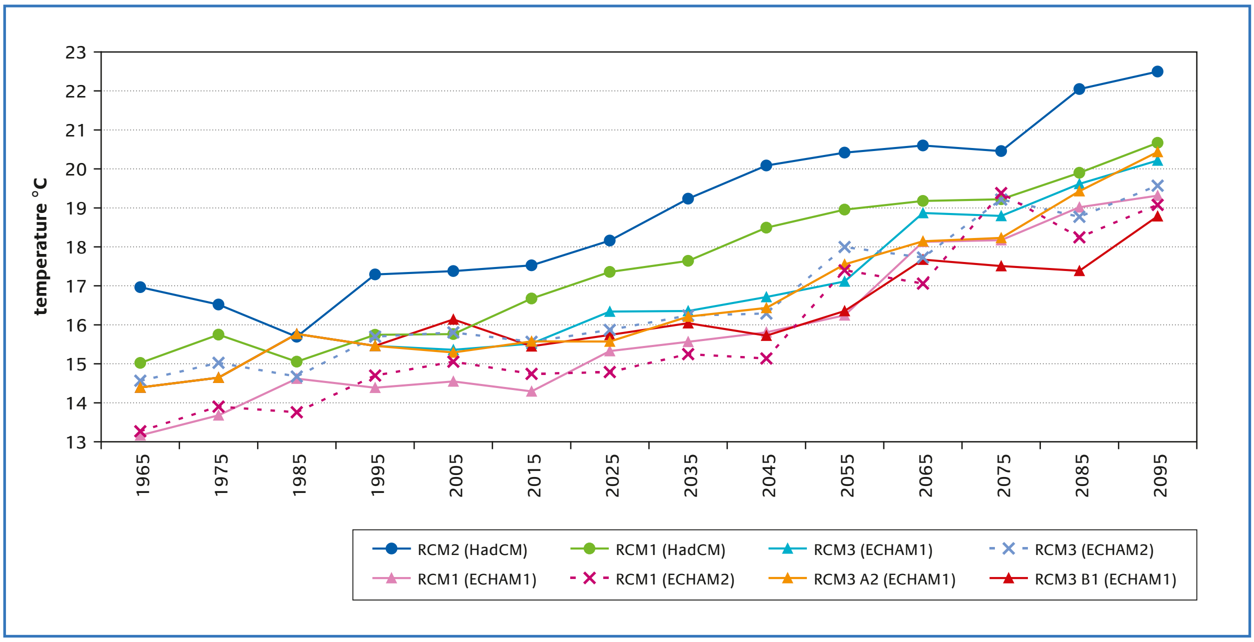

Fig. 9: Maxau: decadal regional temperature mean [°C] for the months June to August, calculated by 3 regional climate models, driven by 2 global climate models, for SRES A1B and additionally RCM3 (ECHAM1) also for SRES B1and A2

summer, a clear decrease in precipitation in the last decades of the 21st century can be recognised in all the simulations (Fig. 11).

It is particularly noteworthy that for the region under consideration here, the range for temperature and precipitation changes from the regional climate projections is not increased by the projections of the RCM3 with ECHAM1 driver when allowing for the extreme SRES scenarios B1 and A2. Furthermore, it is apparent that the decadal variability of the regional climate projections clearly depends on the driving global climate model.

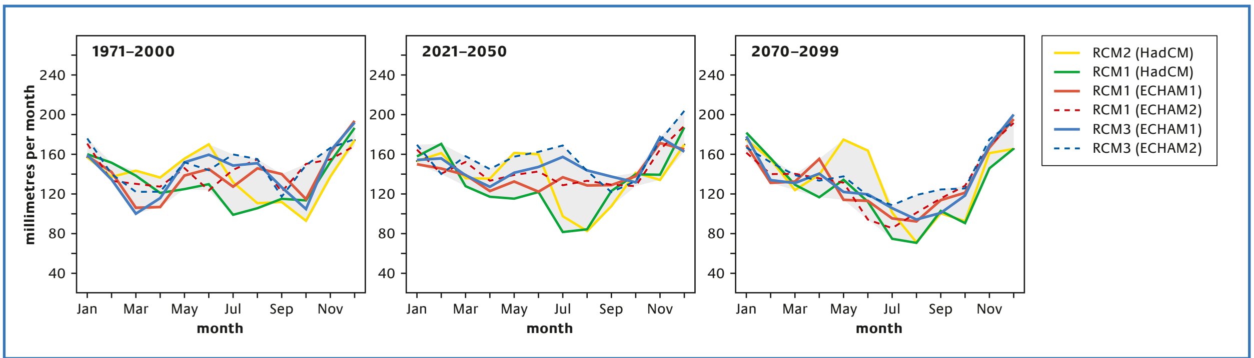

Fig. 10: Maxau: 30-year regional mean for monthly precipitation amounts [mm/month] for the periods 1971–2000, 2021–2050, 2070–2099, calculated by 3 regional climate models, driven by 2 global climate models, for SRES A1B

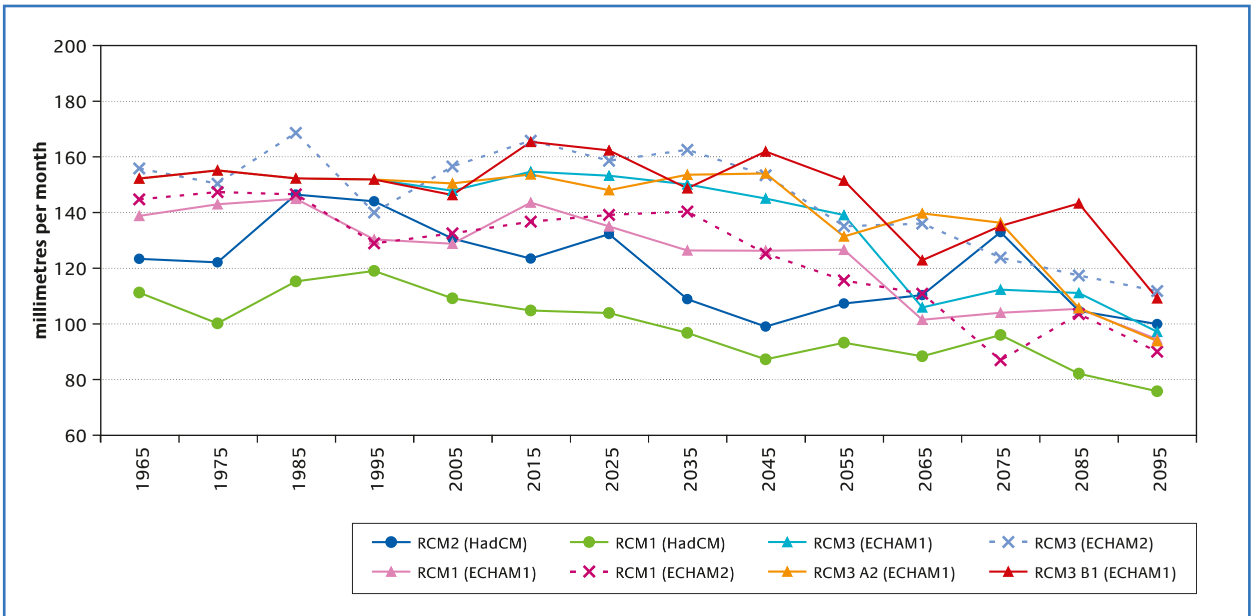

Fig. 11: Maxau: decadal regional mean precipitation amount [mm/month] for the months July to August, calculated by 3 regional climate models, driven by 2 global climate models, for SRES A1B and additionally by RCM3 (ECHAM1) also for SRES B1and A2

5 Summary / Looking to the Future

The validation of the regional climate models demonstrates a relatively good correlation of the parameters under consideration with the observation data. The range for temperature is 2 °C, but the observations were only underestimated by the regional models for winter. The yearly hydrograph of the observed monthly precipitation amounts is represented by the regional models, although the range indicated is considerable.

There is no one model that stands out particularly, but individual fluctuation ranges or deviations from the observation data can be considerable. This illustrates how important it is to determine the whole range of all available climate projections, even for studies of the present-day climate. Therefore, it is important not to be limited to just a few models for the analysis of possible climate changes but, on the contrary, the largest possible ensemble of climate projections must be taken into consideration.

The preliminary results of the regional climate projections are strongly dependent on the selection of the global model. The range of climate projections can be increased by the use of different regional and global climate models. The range of temperature projections varies between 1 and 2 °C in winter and between 3 and 4 °C in summer with decadal fluctuations. All climate projections show a clear rise in temperatures during the 21st century. This prediction of change can be considered to be robust.

The range of precipitation amounts varies less in winter than in summer with decadal fluctuations. All climate projections show a robust decrease in summer precipitation towards the end of the 21st century. However, for this catchment area, this seems to be independent of which emissions scenario is used. This conclusion must, however, be confirmed by further studies and cannot yet be described as robust.

The evaluations that have been presented here, in extracts and provisionally, will be carried out for all available regional climate projections. Furthermore, the range for extreme temperatures and dry periods should prove to be extremely interesting. In addition to the results of the dynamic "downscalings", the results of the statistical "downscalings" of the STAR method of the PIK and the WETREG method of the CEC will be taken into consideration. All studies are to be carried out at a later date for other major Central European river basins (e.g. Elbe, Danube).

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Acknowledgements

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Discharge Scenarios for the Rhine of the 21st Century

Maria Carambia (BfG) & Roy Frings (BfG)

1 Introduction

In the context of the project "Hydrology and Inland Navigation", which is part of the research programme "KLIWAS – Impacts of Climate Change on Waterways and Navigation – Development of adaptation options", attention is focused on the changes in the water balance of the rivers Rhine, Elbe and Danube and on the potential consequences for inland navigation and the shipping industry as a result of climate change.

For the analysis of the above mentioned issues, it is necessary to generate projections for discharge, water depths and flow velocities which are calculated at the Federal Institute of Hydrology (BfG) using model chains consisting of hydrological, hydrodynamic and morphological models.

The main focus of this contribution is on the discharge projections for the international Rhine catchment area downstream to the German-Dutch border which were determined using a hydrological model forced by climate projections. Examplarily, some of the preliminary analyses for the Rhine gauges at Maxau, Kaub and Cologne are presented.

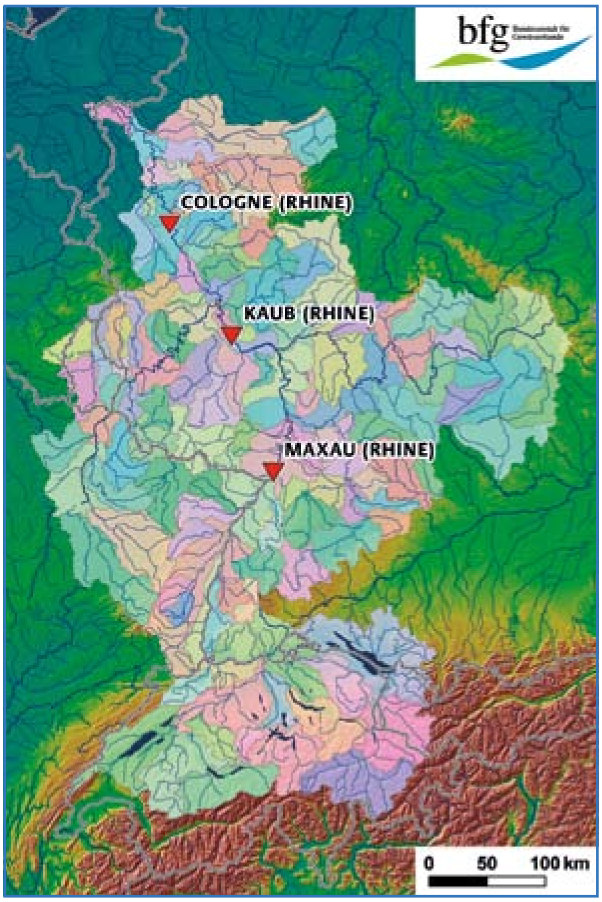

Fig. 1: International catchment of the River Rhine downstream to the German-Dutch border in a spatial subdivision into 134 sub basins and the Maxau, Kaub, and Cologne gauges

2 Methodology

Hydrological modelling was carried out with the model system Hydrologiska Byråns Vattenbalans-avdelning (HBV) which was developed by the Swedish Meteorological and Hydrological Institute (SMHI) in the 1970s (Bergström 1976, 1992). The model application is based essentially on the daily model that was calibrated for 134 sub basins of the international Rhine catchment area downstream to the German-Dutch border (cf. Fig. 1) (Eberle et al. 2005).

Daily areal values for precipitation, temperature and potential evapotranspiration are required as input data for the modelling process with HBV. Grass reference evaporation according to Penman-Wendling (ATV-DVWK 2002) is used as the potential evapotranspiration. This is computed from the climate parameters temperature and sunshine duration / global radiation. On the basis of the available climate projections (cf. Chapter 3), areal values for precipitation, temperature and sunshine duration /global radiation are first determined using the Thiessen polygon method and subsequently prepared for hydrological modelling using a method for the correction of the systematic error of the mean value (bias).

3 Data

Altogether twenty-four climate projections (see contribution by Nilson in this volume) based on three emissions scenarios, four global climate models and six regional climate models were used to produce discharge projections. In addition, hydrometeorological observation data was used to construct a reference run with the model system HBV: the observed precipitation values are available as 25 × 25 kilometre grid values and were prepared during the current EU project ENSEMBLES (ENSEMBLES Partner 2009). The data for temperature and sunshine duration derives from 49 climate stations (Eberle et al., 2005).

4 Results

The discharge projections that have been generated so far were analysed for the time periods 1971–2000 (control period), 2021–2050 ("near future") and 2071–2100 ("distant future"). However, the complete span of simulations is not yet available. Furthermore, the evaluation of the base data has not yet been completed (cf. Nilson, in this volume). For this reason, we will not present the intermediate results in full.

The diagrams shown here represent only exemplary analyses of HBV simulations which are based on the control runs of the climate models (C20, 1971–2000). By comparing this data with the analysis of the reference run, that is, of an HBV simulation, using the observation data described in Chapter 3, it is possible to gain an impression of the uncertainties of the model chain.

The general findings on the future projections have been described in the text but eliminated from the figures. More detailed information is available on request.

4.1 Mean Discharges

For the Rhine gauges at Maxau and Cologne, mean monthly discharges (MoMQ) displaying the discharge regimes were determined for the periods 1971–2000, 2021–2050 and 2071–2100 on the basis of 8, 11 and 10 discharge projections respectively.

Figure 2 shows exemplarily the MoMQ at Maxau gauge with reference to the period 1971–2000. In addition, the span of the MoMQ defined by these discharge simulations is highlighted in grey. The MoMQ on the basis of the HBV reference run is depicted as a black line.

In general, the C20 simulations reproduce the annual cycle of the reference run. However, the reference MoMQ is usually located at the edge of the span of the simulations. In the months March and August, all discharge simulations overestimate the reference MoMQ, whereas in the months October and November, the estimation of the MoMQ is generally too low. A similar

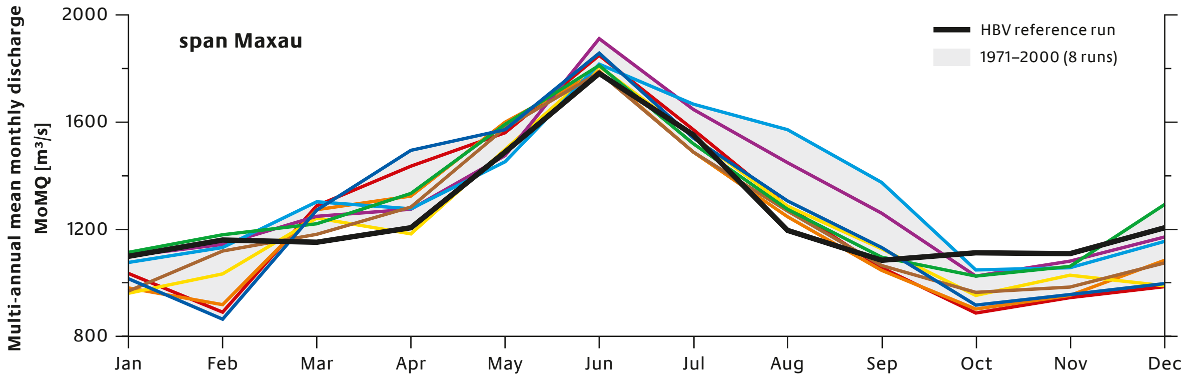

Fig. 2: Gauge Maxau: MoMQ based on 8 discharge simulations and the reference run, with reference to the period 1971–2000

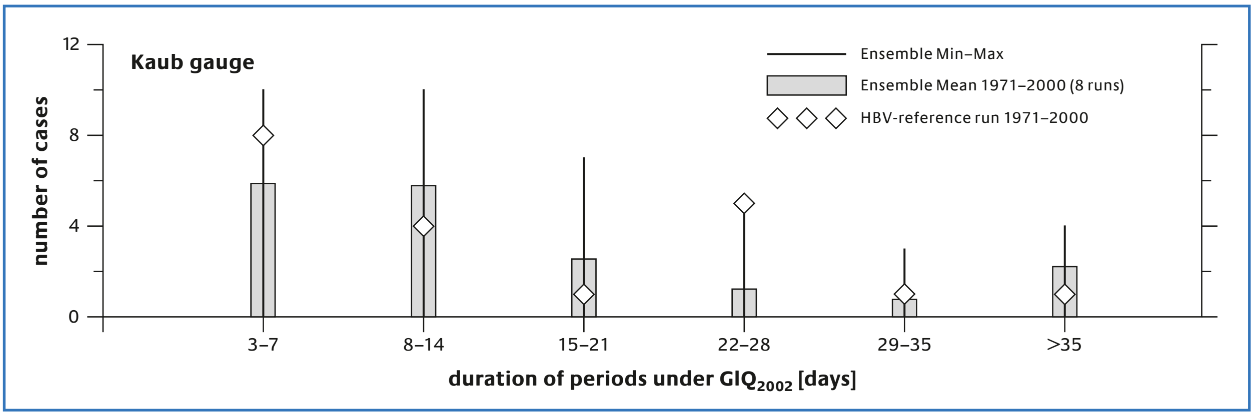

Fig. 3: Duration of periods under GlQ_{2002} = 750 m^3/s at Kaub gauge in the period 1971–2000

picture is revealed for the Cologne gauge. Here, the MoMQ for the period 1971–2000 based on the reference run also lies predominantly in the span of the MoMQ values based on C20. Estimations for individual months (March, May) are, however, too high.

In the period 2021–2050, the span of the MoMQ increases for both Rhine gauges. In comparison with the period 1971–2000, though, it is of a similar magnitude. For the “distant future” (2071–2100) there is a tendency of the discharge projections when compared with the period 1971–2000 towards a decrease in discharge in the summer months and an increase in the winter months.

4.2 Low Water

With reference to Kaub gauge, the duration of periods under a threshold GlQ_{2002} was determined for the time slices 1971–2000, 2021–2050 and 2071–2100 on the basis of the preliminary discharge projections. The threshold “GlQ” (at Kaub gauge: GlQ_{2002} = 750 m^3/s corresponding to the water level GlW_{2002} = 80 cm) is defined as discharge that is undershot on no more than 20 ice free days per year in the 10 year mean. This value represents an important threshold value for navigation.

For the periods 1971–2000, 2021–2050 and 2071–2100, the number of cases was analysed in which the discharge dropped continuously on 3–7, 8–14, 15–21, 22–28, 29–35 and more than 35 days below the GlQ_{2002}. Here the ensemble of discharge simulations mentioned in section 4.1 is considered. Assuming an equal probability for each discharge projection, the “ensemble mean” and the span defined by the ensemble minimum and maximum were calculated for each category of duration.

As an example, Figure 3 shows the ensemble mean values and spans for the period 1971–2000 on the basis of the preliminary discharge simulations with reference to the above-mentioned categories of duration periods. Once again, this is compared with the analysis of the HBV reference run. It is apparent that the number of events in the various classes on the basis of the HBV reference run and the ensemble mean value are predominantly in a similar magnitude. Larger deviations are displayed only in the category of 22–28 day periods. The span of the C20 simulations generally indicates significant uncertainties of this analysis.

The analyses for the “near future” (2021–2050; not illustrated) do not show any significant change in ensemble mean values in the individual duration categories in comparison with the control period. The span is also similar.

For the “distant future” (2071–2100; not illustrated), the ensemble mean values indicate an increasing frequency of low water events in all categories of duration of lower deviations, when compared with the control period (1971–2000). However, comparison of the ensemble mean values of the period 2071–2100 and analogous analyses based on the observed discharge data (periods 1911–1940, 1941–1970; not illustrated) demonstrates that the low flow frequencies determined for the "distant future" have already occurred once in the past in most of the categories in a similar number of occasions. One exception is the duration category >35 days under GlQ_{2002}; this occurs more frequently in the projection. However, in this category the span is found to be particularly large.

5 Summary and Outlook

The data that has been analysed so far shows that the discharge simulations which were generated on the basis of climate model data reflect well the main characteristics of the reference simulation within the control period (1971–2000). Regional and seasonal deviations do, however, also occur.

The analyses which have been carried out with regard to the future (gauges Maxau, Kaub and Cologne) are still to be regarded as exemplary and preliminary in nature. No significant changes in the mean seasonal discharges are indicated for the Maxau and Cologne gauges in the "near future" (2021–2050). The duration of deviations lower than GlQ_{2002} at the Kaub gauge, which were analysed as an example and are relevant to navigation, also do not differ significantly from the values of the control period. Tendencies of the discharge projections towards a decrease of mean discharge in the summer and an increase in the winter can be identified for the scenario horizon 2100. The frequency of periods under GlQ_{2002} varying in duration also generally increases in comparison with the period 1971–2000, but most of the time without exceeding the historically documented fluctuation range (for instance, 1941–1970).

It should be kept in mind that the span of the discharge simulations based on climate model data is considerable. The focus of the next work is to check and, where necessary, to improve the reliability of the analysis. This will be achieved, for instance, by completion of the model ensemble, the use of statistical tests and other bias correction methods. Furthermore, there are plans to include other hydrological models in the studies, to analyse additional hydrological variables and parameters with relevance to navigation and to expand the studies to other river basins (Elbe, Danube).

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From Climate Projections to the Hydrological Scenario: Methodological Aspects

Peter Krahe (BfG) & Enno Nilson (BfG)

1 Introduction

The system of inland navigation, with its most important elements – waterways, shipping fleet, ports and the industries that are dependent on water transport– depends in numerous ways directly or indirectly on natural and anthropogenic climate change (IPCC, 2007). The most important parameter is discharge, which directly determines the water level through the available water depth and, thus, the navigability of the free flowing stretches of the network of German federal waterways. River morphological processes which, in turn, can affect the water level by causing changes in the river bed are impacted, too. The main factors controlling the dynamics of discharge are the hydrometeorological parameters precipitation and potential evaporation and air temperatures at the surface. The latter determine the state of the precipitation (solid, liquid) and the accumulation and reduction of snow cover. Furthermore, it influences the state of the soil water in the uppermost soil layers (liquid, frozen), which influences the formation of discharge through the magnitude of the so-called direct discharge or of the filling of the soil water storage. This affects both high water and low water events. Finally, the air temperature controls the formation and break-up of drift ice and closed ice covers on free-flowing and impounded rivers and canals.

The knowledge of the climate parameters mentioned above in the form of climatic mean values over periods of many years, statistics of extreme values and in the form of time series of observed values and forecasts of several-days, represents, in connection with hydrological modelling, an important basis for many water management planning and decision-making processes. For mid-term and long-term planning, it has hitherto been assumed that the statistics derived from the observation sequences are also valid for the future, that is, at least for the next ten to fifty years.

Modern climate research has made it possible to detect anthropogenic causes of climate change and to describe conceivable changes in important climate parameters in the form of projections and scenarios for the future. Following a period in which protection of the climate "from people" was given higher priority ("mitigation"), there is now increasing discussion on adaptation, i.e. the protection of people from the consequences of possible climate change. In this respect, it is necessary to investigate both the risk situation as a result of undesirable climatic impact and the appropriateness of proposed measures or of strategies that must still be developed.

This is the subject of the KLIWAS research programme "Impacts of Climate Change on Waterways and Navigation in Germany" which will proceed according to the steps shown in Figure 1. In the context of

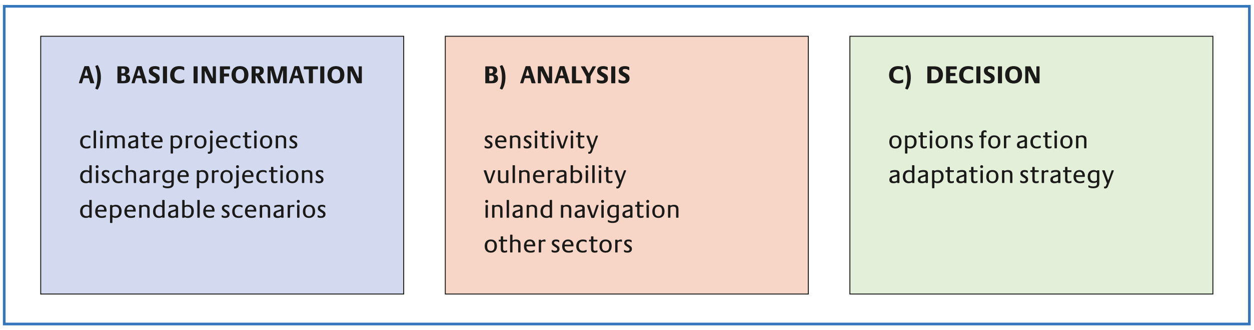

Fig. 1: Diagram of the "three pillars of decision-making" for an adaptation strategy

the KLIWAS project 4.01, "Hydrology and Inland Navigation", besides making an analysis of the susceptibility and the potential for adaptation of inland navigation and of the associated economic sectors, the climate projections available at present will be processed and this information will be converted into discharge projections. A uniform procedure for the development of projections for the various river basins of Germany, including their international parts, will be defined. Furthermore the uncertainties of the different models and methods required for the calculation of the projection will be determined.

Following the terminology of the IPCC (2007), the term "projection" will be used in the sense of first dealing with model results that have not yet been evaluated, that is, values of the future course of climate and discharge that are derived from models and model chains. By contrast, a "scenario" depicts a coherent, internally consistent and plausible (i.e evaluated) description of a possible future state. Accordingly, it is not a prediction, but every scenario is an alternative picture of how the future could appear. Parry (2000) describes the scenario technique as an aid in the dialogue between the scientific world and the decision-makers which is useful for organising the better-known aspects and the less-known aspects into a series of pictures of the future. The purpose of scenarios is not, therefore, to predict the "true" future, but to demonstrate a range of possible future developments.

The climate and discharge projections that have been prepared so far in the scope of this project thus form a basis for the production of discharge scenarios which must still be derived for further hydrological, transport and water management issues in climate impact research. The results presented here require further checking, evaluation and, possibly, correction in cooperation with Task 1 (see contribution by Rudolf et al. in this volume). Further information and hypotheses (for instance, in regard to land use) must be included in order to draw up the scenarios. In what follows, we will present some known aspects and concepts for the production of regional climate scenarios for the River Rhine catchment.

2 Global Emissions Scenarios and Climate Projections

Statements on future climate development first require assumptions on the future development of the emissions of the so-called greenhouse gases. As these will be determined by future human action, and because no precise prediction or forecast can be made for the socio-economic, demographic and technological development of society, scenarios for the future development of greenhouse gas emissions are determined on the basis of assumptions agreed on regarding development trends that appear possible in the future. Some of the 35 scenarios, the so-called SRES scenarios (Special Report on Emission Scenarios, Nakićenović et al. 2000) that have been agreed in international bodies are now commonly used. These scenarios were divided into four families of scenarios (A1, A2, B1, B2) which, in turn, are represented by six standard scenarios. As climate simulations are very costly, the Fourth Report of the IPCC (IPCC, 2007) was confined exclusively to the three "marker" scenarios B1 ("moderate"), A1B (medium) und A2 ("extreme") (IPCC, 2007). These are commonly used by most research groups as an input parameter for the complex global climate models. In regional climate studies a further restriction is often applied for pragmatic reasons, so that only the "medium" A1B scenario is used.

For the analysis, the mean values from the period 1971–2000 (reference climate, actual climate) and the scenario horizons 2021–2050 and 2071–2100 are often taken for purposes of comparison. In some publications, however, other periods are chosen for the reference climate and compared with the 20s, 50s and 80s of the 21st century. The averaging periods may vary, too.

3 Regional Climate Scenarios in the Rhine Region

In the scope of the cooperation project "Climate Change and Consequences for Water Management" (KLIWA) between the German federal states Baden-Württemberg, Bavaria and Rhineland-Palatinate and the German

Meteorological Service (DWD), precisely one climate projection was selected from three regional climate projections (Hennegriff et al. 2006) that were available for the KLIWA project region in 2004. This projection was considered by the water management authorities in Bavaria and Baden-Württemberg as a scenario for further evaluations with respect to decisions about adaptation measures in the field of flood risk management.

Because of their special situation (low-lying land; coastal region; downstream residents of the two major rivers Rhine and Meuse), the Netherlands are at particular risk from a possible climate change in terms of high water problems. Thus, a long tradition of defining climatic scenarios for the state territory and the cross-border river basins and applying these in planning issues already exists here. A set of scenarios that was laid down in the year 2006 and which spreads out in the form of four different climate scenarios forms the current working basis (van den Hurk et al., 2006).

Present considerations of international climate (impact) science assume that it is possible to assess the uncertainties inherent in climate and discharge projections for producing global and regional climate scenarios. For this, several climate model runs must be calculated with different models and with each model using various assumptions about initial conditions and parameters which, although different, can be regarded with equal probability as being realistic. The model results are then available in the form of one or several so-called ensembles. With suitable analysis, conclusions on the probability of future developments can be achieved with this method (Frei, 2006). The results of a scenario of this kind are then no longer simply a numerical value, but an expected change in, for example, the mean value of discharge over many years, and is described in the form of a frequency distribution. The uncertainties of future changes in discharge will therefore be quantified by means of probabilities. Probability statements of this kind are known as probabilistic climate or discharge projections. It should be noted that this procedure permits only the estimation of model-predicted and natural climate variability. The impact of the various future greenhouse gas emissions on discharge behaviour can only be carried out through calculation of the various emissions scenarios.

Corresponding precipitation and temperature projections (CH2050) were developed for Switzerland by Frei (2006) on the basis of the results of the EU project PRUDENCE (Christensen & Christensen, 2007). Furthermore, it should be mentioned that a set of projection data is being developed for Great Britain according to this concept (UKCIP09) (Jenkins et al., 2009).

4 Discharge Projections in the Rhine Region

The method of producing probabilistic discharge projections for the large German river basins will also be pursued in the KLIWAS project. This work has not yet been completed. A suitable method is still being developed. The climate projections available at present from diverse national (Hollweg et al., 2008, Jacob et al., 2008) and international projects (ENSEMBLES Partner, 2009) are currently being evaluated, processed and used as inputs for hydrological models to produce discharge sequences (Bülow, Jacob & Tomassini and Carambia & Frings in this volume). Figure 2 shows the discharge projections currently available for the Rhine region, using the example of the number of days under a certain discharge threshold - i.e. the discharge (GLQ) corresponding to the so-called “equivalent water level” (GLW) - which is of significance for water traffic management at the Kaub gauge (AEo = 103.605 km^2). The figure shows 20-year mean values of the annual total of days with lower deviation for the control period 1951-2000 and for the projection period 2001-2100.

To illustrate the span, a compensating curve is drawn through the highest and lowest values. The area shaded in blue in Figure 2 corresponds to the span which was derived from the long series of observation data (1821-2005). In general, an increase in the number of days with under the equivalent water level can be expected towards the end of the 21st century, while it is only after the year 2060 that the majority of the projections differ

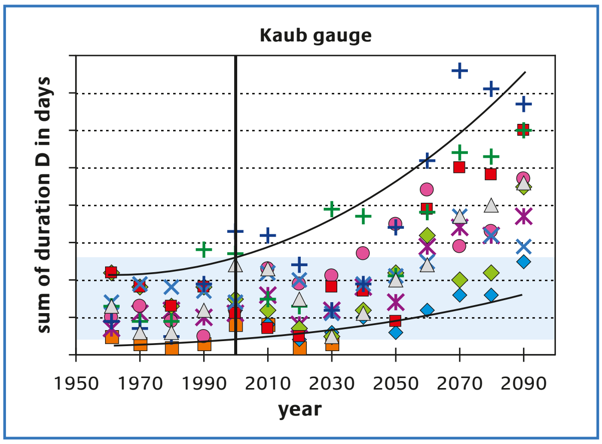

Fig. 2: Number of the days per annum under the so called equivalent water level (GLQ_{2002} = 750 m^3/s) at the Kaub gauge for 20-year averaging periods, using various climate projections based on the three SRES scenarios, B1, A1B and A2. Each symbol refers to a specific model combination. The range that was derived from the observed discharge values for the period 1821–2005 is highlighted in pale blue. The ordinate values have been omitted as these are still only preliminary results.

noticeably from the area derived from the observation data. The curves show a widening in the span in the distant future. This can for the most part be traced back to the different emissions scenarios on which the climate projections were based. It also becomes apparent that the relationship between emissions scenarios and changes in precipitation or discharge are not as unambiguous as they are for air temperature (IPCC, 2007). However, when the results of an emissions scenario are considered using several realisations of a model chain, relatively large differences also occur. These may be ascribed to the inherent, natural variability of climate which becomes more obvious in the discharge series and in the statistics derived from them.

5 Summary / Looking to the Future

The current global and regional climate models which have been prepared and made available by national and international climate researchers on the basis of the Fourth Assessment Report are at present being used as a basis for discharge projections for the Rhine region, using a hydrological model. A preliminary analysis of possible future low water developments in the Rhine region was demonstrated using the example of the Kaub gauge. More detailed analysis is still necessary; for example, it is planned that specific comparisons of the various projections should be made in order to determine an assessment of the methodological (model-related) and the inherent, natural variability of the climate system (decadal variations) in the form of spans. To do this, the uncertainties which are caused by hydrological modelling are still to be evaluated.

Work is still continuing on a methodology which, besides the range of the possible development, will allow the preparation of probabilistic discharge projections by means of statistical correction, evaluation and selection procedures. The special requirements which arise from the analysis of the climate sensitivity of the individual components of the system “inland navigation” and of the economic sectors that depend on it will be taken into account. Furthermore, in the context of the KLIWAS research programme, a concept for communicating these projections, for example, in the form of scenarios will be drawn up.

It has already become clear from the calculations and analyses that have been carried out that the internal climatic variability plays a major role in defining the climate change signal. For future model experiments, it is therefore desirable that specially compiled large ensembles, that is, several runs of one or more global climate models should be produced, in order to determine these uncertainties through an appropriate scenario fan.

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Closing Remarks

The lectures and discussions at the First KLIWAS Status Conference have highlighted the importance of objectivity in the debate on the impact of climate change. One essential foundation for a professional and expert debate is a common understanding of the usage of the most important terms, such as, trend, forecast, prediction, projection and the time horizons related to these. A continual rise in mean global air temperatures has been proved beyond any doubt. However, regional projections on the change in volume and distribution of precipitation, and the resulting discharge volumes in rivers, do not yet permit any clear statement. The first results of the KLIWAS pilot project on the Rhine indicate that climate changes in the next few years will not yet cause any drastic alterations in the mean discharges. Overhasty adaptation measures for the Rhine are therefore not necessary and KLIWAS can proceed with the required scientific precision.

KLIWAS will make a contribution to a scientific basis for narrowing down the very wide present-day spectrum of possible future scenarios. Networking of national and international research is indispensable and is also expressed in the formation of the scientific consultative committee for KLIWAS.

Plans for waterway projects have always required foresightedness and taken into account identifiable changes. Experience of complex influential factors and in particular with uncertainties is thus already available. Even KLIWAS will not be able to do away with all uncertainties, but will create a solid planning base in view of the increasingly rapid rate of climate change. The results that will be acquired by KLIWAS little by little will be published and integrated into the planning measures on an ongoing basis. It will not be a matter of waiting for 5 years until all the KLIWAS projects have been completed. In this way, uncertainties will not restrain us from action. “No regret” measures are the preferred means. These include the full exploitation of technical possibilities for overcoming bottle-necks by means of intelligent traffic guidance and information systems.

Furthermore, KLIWAS will generate new and fundamental knowledge for other sectors, users and interest groups in the river basins and coastal areas, thus contributing to the German Strategy for Adaptation to Climate Change (Deutsche Anpassungsstrategie an den Klimawandel, DAS). The inclusion of the results in political advising and in the planning of maintenance and infrastructure will take place as they become available, and as quickly as possible.

If all the organisational preparations can be concluded by the middle of this year, KLIWAS can and will gather momentum during the next weeks and months, with greater intensity and in its full measure. Perception of and interest in these developments will increase noticeably. It is important that during this process, the knowledge carriers of science and practice (Waterways and Shipping Administration – WSV, the Länder) are involved right from the start, but the challenge also goes out to the stakeholders from the business world and the environment associations to support this process. Communication within this alliance and with external partners will play a key role in the success of KLIWAS.

The high level of interest in KLIWAS and the significance of KLIWAS have been impressively documented in the statements of the many and diverse participants in this conference. This is a good beginning, from which everything else may, and will, continue to develop.
I wish all participants great success with this venture.

Reinhard Klingen,
Director of the Directorate “Waterways”
at the BMVBS (Federal Ministry of Transport, Building and Urban Development)

List of Abbreviations

ARGO Array for Real-time Geostrophic Oceanography

b = billion(s)

BAW Federal Waterways Engineering and Research Institute (*Bundesanstalt für Wasserbau*)

BfG Federal Institute of Hydrology (*Bundesanstalt für Gewässerkunde*)

BMBF Federal Ministry of Education and Research (*Bundesministerium für Bildung und Forschung*)

BMELV Federal Ministry of Food, Agriculture and Consumer Protection (*Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz*)

BMU Federal Ministry of the Environment, Nature Conservation and Nuclear Safety (*Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit*)

BMVBS Federal Ministry of Transport, Building and Urban Development (also: Federal Ministry of Transport, Building and Urban Affairs) (*Bundesministerium für Verkehr, Bau und Stadtentwicklung*)

BSH Federal Maritime and Hydrographic Agency (*Bundesamt für Seeschifffahrt und Hydrographie*)

CCNR Central Commission for the Navigation on the Rhine

CEC Climate & Environment Consulting Potsdam GmbH (located at the → PIK)

CHMI Czech Hydrometeorological Institute

CHR International Commission for the Hydrology of the Rhine Basin

CLM Climate Local Model

CSC Climate Service Centre

DAS German Strategy for Adaptation to Climate Change (also: German Adaptation Strategy to Climate Change) (*Deutsche Anpassungsstrategie an den Klimawandel*)

DFG German Research Foundation (*Deutsche Forschungsgemeinschaft*)

DST Development Centre for Ship Technology and Transport Systems (*Entwicklungszentrum für Schiffstechnik und Transportsysteme e.V.*), Duisburg

DWD German Meteorological Service (also: National Meteorological Service of Germany) (*Deutscher Wetterdienst*)

ECHAM Global climate model by MPI Meteorology

ECMWF European Centre for Medium-Range Weather Forecasts

EIS Environmental impact study

ERA Environmental risk assessment

ES Europe ship

EU European Union

EZMW (German abbreviation of → ECMWF)

FD Flood Directive of the European Union

GCM General Circulation Model

GKSS Research Centre in the Helmholtz Association of German Research Centres

GlQ/GLQ Equivalent discharge

GlW/GLW Equivalent water level

GMS Large motorised freight ship (also: large motor vessel)

GRDC Global Runoff Data Centre

GWL Continental scale weather pattern (German: *Großwetterlage*)

HABAB(-WSV) Directive for Dredged Material Management in Federal Inland Waterways (*Handlungsanweisung für den Umgang mit Baggergut im Binnenland der WSV*)

HABAK(-WSV) Directive for Dredged Material Management in Federal Coastal Waterways (*Handlungsanweisung für den Umgang mit Baggergut im Küstenbereich der WSV*)

HadCM Global climate model of the Hadley Centre for Climate Prediction and Research

HBV (Hydrologiska Byråns Vattenbalansavdelning) Hydrological model of the SMHI (Swedish Meteorological and Hydrological Institute)

HD Habitats Directive of the European Community (also: FFH Directive, Fauna-Flora-Habitats Directive)

HFR University of Applied Forest Sciences - Rottenburg (*Hochschule für Forstwirtschaft Rottenburg*)

IKSR German abbreviation of the *International Commission for the Protection of the Rhine (ICPR)*

IPCC Inter-Governmental Panel On Climate Change

KHR German abbreviation of the *International Commission for the Hydrology of the Rhine Basin (CHR)*

KLIMZUG Research programme of the BMBF "Climate change in the regions"

KLIWAS Research programme of the Federal Ministry of Transport, Building and Urban Development "Consequences of Climate Change for Waterways and Navigation in Germany" (*Auswirkungen des Klimawandels auf Wasserstraßen und Schifffahrt in Deutschland*)

KNMI Royal Netherlands Meteorological Institute

KomPass Competence Centre on Global Warming and Adaptation at the German Federal Environmental Agency (*Kompetenzzentrum Klimafolgen und Anpassung*)

m = million(s)

MoMQ Mean monthly discharge

MPI Max Planck Institute

MPI-M Max Planck Institute for Meteorology

NKB North German Climate Office (*Norddeutsches Klimabüro*)

NM7Q Lowest discharge rate averaged over 7 days within a reference time period

oWLK Objective weather situation classification (*objektive Wetterlagenklassifikation*)

PIANC Permanent International Association of Navigation Congresses

PIK Potsdam Institute for Climate Impact Research (*Potsdam-Institut für Klimafolgenforschung e.V.*)

REMO Regional Climate Model of the Max Planck Institute for Meteorology

SEA Strategic environmental assessment

SMHI Swedish Meteorological and Hydrological Institute

SRES Special Report on Emissions Scenarios

ÜGMS Extra-large motorised freight ship (*Übergroßes Großmotorgüterschiff*)

UNESCO United Nations Educational, Scientific and Cultural Organization

VV 1401 Administrative ordinance (*Verwaltungsvorschrift*) of the WSV (German Federal Waterways and Shipping Administration), German Federal Waterways Law (*Bundeswasserstraßenrecht*)

WFD Water Framework Directive of the European Union

WHG German Federal Water Act (*Wasserhaushaltsgesetz*)

WMO World Meterological Organization

WSD (Regional) Waterways and Shipping Directorate of the WSV (*Wasser- und Schifffahrtsdirektion*)

WSV German Federal Waterways and Shipping Administration (*Wasser- und Schifffahrtsverwaltung*)

ZWEK Compilation of Datasets for Climate Impact Assessment (*Zusammenstellung von Wirkmodell-Eingangsdatensätzen für die Klimafolgenabschätzung*), a project of the DWD (German Meteorological Service)

Glossary

Model chain
Several → models which are coupled together in a sequence, in which a subsequently added model further processes the data from the previous model

Circulation pattern
Typical form of (usually) large-scale (atmospheric or oceanic) flows

Climate
Climate is defined as the summation of weather phenomena which characterise the average conditions of the atmosphere at a specified location or in a larger or smaller region.
It is represented by statistical overall features (mean values, extreme values, frequencies, persistent values and others) over a sufficiently long period of time. In general, a period of 30 years is taken as the basis, the so-called normal period (e.g. 1961–1990); however, it is not unusual for shorter periods to be used.

Climate element (frequent synonyms: climate parameter, climate variable)
(Primary) climate elements are climate parameters which can be measured or observed directly, e.g. air temperature, wind, cloud cover, precipitation, duration of sunshine etc.

Climate model
→ Model for → simulation of a → climate

Climate projection
→ Projection of a → climate

Climate simulation
→ Simulation of a → climate

Climate variable
synonym for → climate element

Discharge
The discharge Q states the volume related to a specific catchment area that flows through a specified cross section area in a unit of time.

Discharge projection
→ Projection of the → discharge

Discharge simulation
→ Simulation of the → discharge

Downscaling
Method for the derivation of local or regional information from large-scale models or data (e.g → global models). Two main approaches can be distinguished:
a) Dynamic downscaling uses
→ regional climate models.
b) Statistical (or empirical) downscaling uses statistical relationships which link large-scale atmospheric variables with local/regional climate variables.

Ecological integrity
Ecological integrity refers to the natural characteristics and functions of an ecological system. This also includes the ability to maintain these characteristics and functions in the face of disturbances (e.g., a development of biodiversity and balance of matter specific to a river under the influence of climate change).

Emission scenarios
→ scenarios of future emission volumes of
→ greenhouse gases, e.g. → SRES
Greenhouse gas concentrations, which ultimately form the basis for climate projections, are calculated on the basis of emissions scenarios.

Ensemble (meteorological)
A group of parallel → model simulations for
→ projections or → forecasts.
The → span of results of the individual ensemble runs permits the estimation of uncertainties. Ensembles which are based on precisely the same (climate) model, of which, however, the initial conditions are varied, characterise the uncertainties which are related to the internal variability of the system being modelled (e.g. the climate system). Multi-model ensembles based on simulation with different (climate) models furthermore demonstrate the uncertainties that are associated with diverse model versions, types and variants. Ensembles in which individual model parameters are systematically varied (so-called “perturbed parameter ensembles”) aim to provide a more objective estimation of

the model uncertainty than traditional multi-model ensembles.

Estuary
Funnel-shaped area of a tidal river where it flows into the sea

Eutrophication
Usually an anthropogenically caused enrichment of foods or nutrients which accompanies very intense formation of organic substances

Evapotranspiration
The combined amount of evaporation from the soil surface, the surface of waters, interception evaporation (evaporation from the surfaces of plants) and transpiration (biotic processes, stomatal transpiration)

Forecast
here: when a → projection is categorised as "highly probable," it becomes a forecast. A forecast is produced with the help of deterministic → models which permit statements on a statistical confidence level.

Global model
Global climate model or GCM → climate model for the whole earth. The resolution of the GCMs on which the Fourth Assessment Report of the IPCC is based is too coarse for use for regional or local issues. For this purpose, so-called → downscaling is used.

GlQ/GLQ (Equivalent discharge)
Discharge which results at a river cross section at → equivalent water level

GlW/GLW (Equivalent water level)
Low water level which is not exceeded on 20 ice-free days per year in the long-term mean. Important water level value for the assessment of conditions in the navigation channel

Departmental research
Research and development activities of (German) federal and state institutions whose main task is the provision of political advice for government departments, in the form of the scientifically-based knowledge required for decision-making. Furthermore, most of these institutions provide important, research-based services in the fields of testing, licensing, formulation of regulations and monitoring that are in part defined by law.

Greenhouse gases
Gaseous components of the earth's atmosphere which cause the greenhouse effect. The gases (including H_2O, CO_2, N_2O, CH_4, O_3) are of natural and anthropogenic origin. They absorb the radiation emitted from the earth's surface, clouds or the atmosphere itself in specific wave lengths within the spectrum of thermal infra-red radiation.

Impact analysis
here: analysis of the extent to which a system is impacted by climate change

Low flow surcharge
Surcharges added to the basic freight costs in inland navigation, and agreed by contract, as compensation for the restricted capacity of vessels during low water periods

Model
Schematic reproduction of a system with regard to selected characteristics and processes, e.g. for a catchment area

Multi-model approach
see → Ensemble

Neophytes
Plants which have been introduced purposely or accidentally, directly or indirectly, to an area in which they had not normally been found.

Objective classification of weather situations
The objective classification of weather situations is a method for classifying weather conditions based on data from grid point values from weather forecasts or climate models.
The criteria for categorising weather situations may vary. A procedure developed by the German Meteorological Service (DWD) includes the following criteria: a) cyclonality or anticyclonality of flows close to the ground and in the mid-troposphere, b) large-scale direction of flow and c) moisture content of the atmosphere.

Prediction
here: synonym for → forecast

Projection
here: estimation of the future climate (or discharge etc.) with the aid of → models based on given → scenarios

Span
here: the maximum difference between the smallest and largest value of an → ensemble at any given time; e.g. the difference between the smallest and largest mean monthly value of the → discharge over many years

Reference climate
Climate during a → reference period (e.g. normal period 1961–1990)

Reference period
A reference period is a period from which the measurements are applied as a norm for comparison with measurements from another period of time.

Regionalisation
here: synonym for → downscaling

Regional model, regional climate model, RCM
→ Climate model which takes into account the special processes and characteristics of a selected region of the earth with a higher spatial resolution and, thus, a more refined process simulation. It is used for the → regionalisation of data from a → global model.

Satellite altimetry
A process of remote investigation by satellite with the objective of deducing the height of sea level. Radar impulses are emitted from a satellite and received again after being reflected back from the surface of the water. The time taken for the impulse is used to calculate the height of the satellite above the surface of the ocean. Simultaneously, the position of the satellite is used to calculate its height above the earth's ellipsoid. The difference between the two values reveals the height of sea level above the ellipsoid. This is the sum of the so-called geoid height (which represents a mean, resting ocean surface) and the so-called ocean surface topography. If their surface areas are large enough, inland bodies of water and frozen surfaces can also be observed.

Scenario
A plausible and often simplified description of the future development.
A scenario is based on a coherent and internally consistent bundle of assumptions with regard to the future driving forces and their interdependence. Scenarios may be derived from → projections, but frequently require additional data from other sources, sometimes in combination with so-called → story lines.
The scenarios on which the current → climate projections are based are the → SRES scenarios.

Sensitivity
here: Sensitivity is the degree to which a system can be influenced (negatively or positively) by climate change or climate variability.
The effect may be direct (e.g., through the influence of mean annual temperature amplitude on harvest yields) or indirect (e.g., damage caused by flooding caused by a rise in sea level that is a result of climate change).

Simulation
Use of a → validated → model to study the behaviour of a system being observed under certain conditions (e.g. → scenarios)

SRES Scenarios
SRES scenarios are emissions scenarios, the → story lines of which are defined in the "Special Report on Emissions Scenarios" (abbr.: SRES) (Nakićenović et al. 2000). They form, amongst others, the basis for climate projections of the Fourth Assessment Report of the IPCC. In the contributions in this volume, three selected SRES are considered (ref. no: A2, B1 and A1B); their story lines are based on the differing weightings between a) economic and environmental orientation of society and b) globalisation and regional development.

SRES scenario families
→ SRES scenarios which assume a similar demographic, social, economic and technical development are integrated into the scenario families (A1, A2, B1, B2).

Story line
A narrated description of a scenario which includes the essential characteristics and interrelations between the driving forces and their development dynamics.

Uncertainty
An expression of the degree to which a value (e.g. a → climate parameter for the future) is known. Uncertainty may be caused by incomplete or erroneous/inaccurate information. In the context of climate impact research, uncertainties may have many sources. Not all of them can be quantified precisely and some are unavoidable.

Validation
here: testing the validity of a model. Proof of the capability of a → model to simulate the observed behaviour of the system represented by the model.

Verification
Testing of the truth content of a result or a model

Vulnerability
The susceptibility of a system in regard to alterations in conditions and its inability to cope with these conditions

Weather
Weather is defined as the physical condition of the atmosphere at a specific point in time or over a short period at a given location or in a region, as characterised by the → climate elements and their interaction.

Weather forecast
→ Forecast of the → weather

KLIWAS Research Tasks and Projects

(Overview, status as of May 2010)

Meteorological climate scenarios, Research Task 1

Validation and evaluation of climate projections – provision of climate scenarios for application on waterways and navigation

Task management: German Meteorological Service (DWD)
Dr. Annegret Gratzki, Dept. "Hydrometereology", phone: +49 (0)69/8062-2989, annegret.gratzki@dwd.de

Proj. No.	Project management / contact partner		Project (Proj.)
1.01	DWD	Dr. A. Gratzki	Hydrometeorological reference data for river basins
1.02	DWD	J. Namyslo	Provision of application-oriented and evaluated climate projection data
1.03	BSH- DWD	Dr. H. Heinrich G. Rosenhagen	Atmospheric and oceanic reference data and climate projections for coastal and open sea areas

Climate change in coastal and estuarine areas, Research Task 2:

Changes in the hydrological system of coastal waters

Task management: Federal Institute of Hydrology (BfG),
Dr. Stephan Mai, Graduate Engineer, Department M 1, phone: +49 (0)261/1306-5322, mai@bafg.de

Proj. No.	Project management / contact partner		Project (Proj.)
2.01	BSH- DWD	Dr. H. Heinrich G. Rosenhagen	Climate change scenarios for the maritime area und their parametrisation
2.02	BfG	Fr. Dr. A. Sudau	Validation of climate projections for water level changes with regard to tectonic influences at the coast
2.03	BfG	Dr. S. Mai, Graduate Engineer	Climate induced changes in tidal parameters and sea state statistics at the coast
2.04	BAW	Dr. N. Winkel, Dr. E Rudolph	Vulnerability of hydraulic engineering systems at the North Sea and its estuaries due to climate change
ARGO	BSH	Dr. H. Heinrich	Array for Real-time Geostrophic Oceanography

Climate change in coastal and estuarine areas, Research Task 3:

Changes and sensitivity of the water body state (morphology, quality, ecology) and adaptation options for navigation and waterways

Task management: Federal Institute of Hydrology (BfG), **Dr. Werner Manz,** Head of Department G3, as from 1.10.2009: **Dr. Birgit Schubert,** Department G1, phone: +49 (0)261-1306-5312, schubert@bafg.de

Proj. No.	Project management / contact partner		Project (Proj.)
3.01	BSH- DWD	Dr. H. Heinrich G. Rosenhagen	Impacts of climate,change on navigation and other uses of the sea
3.02	BAW	Dr. N. Winkel	Adaptation options for waterways and ports at the German coast and coastal protection in extreme weather events
3.03	BfG	Dr. A. Winterscheid	Impact of climate change on the budget of suspended particulate matters in North Sea estuaries
3.04	BfG	Dr. W. Manz, ab 1.10.2009 Dr. G. Reifferscheid	Impacts of climate change on microbial water quality and their implications for dredged material management in coastal waters
3.05	BfG	Dr. T. Ternes	Impacts of climate change on stability and environmental relevance of hydraulic engineering materials in coastal waters
3.06	BfG	Dr. B. Schubert	Impacts of climate change on the transport behaviour of contaminated sediments and maintenance of coastal waterways
3.07	BfG	Dr. M. Schlüsener	Impacts of climate change on patterns of organic pollutants in coastal waters
3.08	BfG	A. Schöl	Climate change related impacts on the oxygen budget of North Sea estuaries due to alterations of river discharge and nutrient and carbon load – Potential adaptation strategies for navigation and sediment management
3.09	BfG	Fr. E.-M. Bauer M. Heuner	Vegetation shift in German estuaries due to climate change and consequences for bank protection and maintenance

Climate change in inland areas, Research Task 4:

Changes in the hydrological system: sediment budgets, morphology and adaptation options for inland waterways and navigation

Task management: Federal Institute of Hydrology (BfG)
Dr. Thomas Maurer, Graduate Engineer, Department M2 Water Balance, Forecasting and Predictions
Phone: +49 (0)261/1306-5242, thomas.maurer@bafg.de

Proj. No.	Project management / contact partner		Project (Proj.)
4.01	BfG	Dr. E. Nilson	Impacts of climate change on hydrology and management options for the economy and inland navigation
4.02	BfG	Dr. M. Promny	Climate projections for sediment budgeting and river morphology
4.03	BAW	Dr. M. Schröder	Options for the regulation and adaptation of hydraulic engineering measures to climate induced changes of the discharge regime
4.04	BAW	Prof. Dr. B. Söhngen	Minimum width of fairways for safe and easy navigation
4.05	BAW	Dr. T. Maurer	Process studies on the development of ice formation in waterways

Climate change in inland areas, Research Task 5:

Impacts of climate change on structure, ecological integrity and management of inland waterways

Task management: Federal Institute of Hydrology (BfG),
Dr. Helmut Fischer, Department U2, phone: +49 (0)261/1306-5458, helmut.fischer@bafg.de

Proj. No.	Project management / contact partner		Project (Proj.)
5.01	BfG	Dr. G. Hillebrand	Climate projections for sediment budgets and risks due to cohesive sediments
5.02	BfG	Dr. H. Fischer	Impacts of climate change on nutrient and phytoplankton dynamics in navigable rivers
5.03	BfG	Dr. W. Manz, ab 1.10.2009: Dr. G. Reifferscheid	Impacts of climate change on microbial water quality and their implications for dredged material management in inland waterways
5.04	BfG	Dr. T. Ternes	Impacts of climate change on patterns of organic pollutants in inland waters*
5.05	BfG	Dr. T. Ternes	Impacts of climate change on stability and environmental relevance of hydraulic engineering materials in inland waters
5.06	BfG	Dr. P. Horchler	Impacts of climate change on the vegetation of flood plains
5.07	BfG	Dr. J. H. E. Koop	Basics for the adaptation of faunistic evaluation methods due to climate change
5.08	BfG	Dr. S. Kofalk	Indicators for impact evaluation of climate change and for adaptation options at river basin scale

*financed by the BMU

List of participants

Ahrens, Christian
Bundesamt für Bauwesen und Raumordnung (Federal Office for Building and Regional Planning)
53179 Bonn (Germany)

Albers, Meike
Deutscher Industrie- und Handelskammertag e. V. (Association of German Chambers of Industry and Commerce)
10178 Berlin (Germany)

Bachert, Klaus
Hessisches Ministerium für Umwelt, ländlichen Raum und Verbraucherschutz
(Ministry for Environment, Agriculture and Consumer Protection of German Federal State of Hesse)
65189 Wiesbaden (Germany)

Bachert, Roland
Amt für Geoinformationswesen der Bundeswehr (Geographic Information Service of the Bundeswehr)
68623 Lampertheim (Germany)

Barneveld, Hermjan
HKV Hydrokontor GmbH
52068 Aachen (Germany)

Bartels, Klaus
Bremenports GmbH & Co. KG
27568 Bremerhaven (Germany)

Bärthel, Hans
Wasser- und Schifffahrtsdirektion Ost
(Waterways and Shipping Directorate East)
39108 Magdeburg (Germany)

Becker, Paul
Deutscher Wetterdienst
(German Meteorological Service)
63004 Offenbach (Germany)

Behrendt, Michael
Bundesanstalt für Gewässerkunde
(Federal Institute of Hydrology)
56068 Koblenz (Germany)

Beiser, Rüdiger
Wasser- und Schifffahrtsdirektion Südwest
(Waterways and Shipping Directorate Southwest)
55127 Mainz (Germany)

Bejan, Adrian
Wasser- und Schifffahrtsdirektion Süd
(Waterways and Shipping Directorate South)
97082 Würzburg (Germany)

Belz, Jörg Uwe
Bundesanstalt für Gewässerkunde
(Federal Institute of Hydrology)
56068 Koblenz (Germany)

Berg, Hannelore
Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (Federal Ministry of the Environment, Nature Conservation and Nuclear Safety)
53175 Bonn (Germany)

Beul, Birgitta
Wasser- und Schifffahrtsamt Duisburg-Rhein
(Waterways and Shipping Office Duisburg-Rhine),
47198 Duisburg (Germany)

Bialonski, Wolfgang
DST Entwicklungszentrum für Schiffstechnik und Transportsysteme (Development Centre for Ship Technology and Transport Systems)
47057 Duisburg (Germany)

Binder, Nicole
Bundesministerium für Wirtschaft und Technologie
(Federal Ministry of Economics and Technology)
10115 Berlin (Germany)

Blum, Holger
Lower Saxony state agency for Water Management, Coastal Defence and Nature Conservation (NLWKN) – Regional Office Norden-Norderney
26506 Norden (Germany)

Böhme-Korn, Georg
Sächsisches Staatsministerium für Umwelt und Landwirtschaft (Saxon State Ministry of the Environment and Agriculture)
01097 Dresden (Germany)

Böhn, Alexander
Bundesrechnungshof (Supreme Audit Institution of the Federal Republic of Germany)
53113 Bonn (Germany)

Brahmer, Gerhard
Hessisches Landesamt für Umwelt und Geologie (Hessian State Office for Environment and Geology)
65203 Wiesbaden (Germany)

Brügge, Bernd
Bundesamt für Seeschifffahrt und Hydrographie (Federal Maritime and Hydrographic Agency)
20359 Hamburg (Germany)

Brunsch, Christian
Bundesministerium für Verkehr, Bau und Stadtentwicklung (Federal Ministry of Transport, Building and Urban Development)
53175 Bonn (Germany)

Bülow, Katharina
Max Planck Institute for Meteorology
20146 Hamburg (Germany)

Carambia, Maria
Bundesanstalt für Gewässerkunde (Federal Institute of Hydrology)
56068 Koblenz (Germany)

Cemus, Jiri
Wasser- und Schifffahrtsamt Hann. Münden (Waterways and Shipping Office Hann. Münden)
34346 Hann. Münden (Germany)

Cramer, Hubertus
Rijkswaterstaat (Bureau for Water Management)
2500 EX Den Haag (Netherlands)

Cubasch, Ulrich
Institut für Meteorologie (Institute of Meteorology), FU Berlin
12165 Berlin (Germany)

Dalhoff, Simone
Wasser- und Schifffahrtsamt Bremen (Waterways and Shipping Office Bremen)
28199 Bremen (Germany)

Dister, Emil
WWF-Auen-Institut (WWF-Institute for Floodplains Ecology), Karlsruhe Institute of Technology
76437 Rastatt (Germany)

Dosch, Fabian
Bundesforschungsinstitut für Bau-, Stadt- und Raumforschung (Federal Institute for Research on Building, Urban Affairs and Spatial Development)
53179 Bonn (Germany)

Eilts, Meike
Bundesministerium für Verkehr, Bau und Stadtentwicklung (Federal Ministry of Transport, Building and Urban Development)
53175 Bonn (Germany)

Esser, Birgit
Bundesministerium für Verkehr, Bau und Stadtentwicklung (Federal Ministry of Transport, Building and Urban Development)
53175 Bonn (Germany)

Essers, Angela
Bundesrechnungshof (Supreme Audit Institution of the Federal Republic of Germany)
53113 Bonn (Germany)

Fickert, Maja
Hamburg Port Authority
20457 Hamburg (Germany)

Fischer, Helmut
Bundesanstalt für Gewässerkunde (Federal Institute of Hydrology)
56068 Koblenz (Germany)

Fortmann, Hermann-Josef
Evonik Services GmbH
45772 Marl (Germany)

Frings, Roy
Bundesanstalt für Gewässerkunde
(Federal Institute of Hydrology)
56068 Koblenz (Germany)

Füngerlings, Friedrich
Berufsgenossenschaft für Fahrzeughaltungen
(Professional Association for Safety and Training
in the Transport Industries)
47053 Duisburg (Germany)

Gabriel, Thomas
Wasser- und Schifffahrtsdirektion Ost
(Waterways and Shipping Directorate East)
39108 Magdeburg (Germany)

Ganske, Anette
Deutscher Wetterdienst
(German Meteorological Service)
20359 Hamburg (Germany)

Gelinek, Michael
Contrac GmbH
72534 Hayingen (Germany)

Görgen, Klaus
Public Research Centre – Gabriel Lippmann
4422 Belvaux (Luxembourg)

Gratzki, Annegret
Deutscher Wetterdienst
(German Meteorological Service)
63004 Offenbach (Germany)

Grohmann, Christian
SUT Verlags GmbH
53757 Sankt Augustin (Germany)

Grohnwald, Karin
Bundesministerium für Verkehr, Bau und
Stadtentwicklung (Federal Ministry of Transport, Build-
ing and Urban Development)
10115 Berlin (Germany)

Günther, Ulrich
Wasser- und Schifffahrtsamt Bremerhaven
(Waterways and Shipping Office Bremerhaven)
27568 Bremerhaven (Germany)

Gurwell, Birger
Staatliches Amt für Umwelt und Natur
(State Office for the Environment and Nature)
18059 Rostock (Germany)

Haberland, Günter
M. Zietzschmann GmbH & Co. KG
41460 Neuss (Germany)

Hanisch, Hans-Hermann
56132 Miellen (Germany)

Härtel, Friedericke
Wasser- und Schifffahrtsdirektion Ost
(Waterways and Shipping Directorate East)
39108 Magdeburg (Germany)

Hartwig, Karl-Hans
Institut für Verkehrswissenschaft
(Institute of Transport Economics)
Westfälische Wilhelms-Universität Münster
48149 Münster (Germany)

Hauser, Stefan
Bundesministerium für Verkehr, Bau und
Stadtentwicklung (Federal Ministry of Transport, Build-
ing and Urban Development)
53175 Bonn (Germany)

Heers, Franz-W.
Deutscher MotorYacht Verband e.V.
(German Motor Yacht Association)
53123 Bonn (Germany)

Heinisch, Timo
Universität der Bundeswehr München
(Bundeswehr University Munich)
85577 Neubiberg (Germany)

Heinrich, Hartmut
Bundesamt für Seeschifffahrt und Hydrographie (Federal Maritime and Hydrographic Agency)
20359 Hamburg (Germany)

Heinz, Michael
Wasser- und Schifffahrtsdirektion West
(Waterways and Shipping Directorate West)
48147 Münster (Germany)

Heinzelmann, Christoph
Bundesanstalt für Wasserbau (Federal Waterways Engineering and Research Institute)
76187 Karlsruhe (Germany)

Helten, Jürgen
Imperial Reederei GmbH
47119 Duisburg (Germany)

Herzog, Petra
Wasser- und Schifffahrtsamt Mannheim
(Waterways and Shipping Office Mannheim)
68159 Mannheim (Germany)

Heyer, Harro
Bundesanstalt für Wasserbau (Federal Waterways Engineering and Research Institute)
22559 Hamburg (Germany)

Hilger, Beate
University of Koblenz (Germany)

Hoffmann, Jörn
Deutsches Zentrum für Luft- und Raumfahrt e.V. (German Aerospace Center)
53227 Bonn (Germany)

Holtmann, Berthold
DST Entwicklungszentrum für Schiffstechnik und Transportsysteme (Development Centre for Ship Technology and Transport Systems)
47057 Duisburg (Germany)

Hornemann, Corinna
Umweltbundesamt (Federal Environment Agency)
06844 Dessau (Germany)

Jacob, Daniela
Max Planck Institute for Meteorology
20146 Hamburg (Germany)

Jekel, Heide
Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (Federal Ministry of the Environment, Nature Conservation and Nuclear Safety)
53175 Bonn (Germany)

Jensen, Jürgen
University of Siegen
57068 Siegen (Germany)

Kaiser, Ralf
NLWKN – Coastal Research Station
26546 Norderney (Germany)

Kalusch, Oliver
Bundesverband Bürgerinitiativen Umweltschutz
(Federal Association of Citizens' Initiatives on Environmental Protection)
58452 Witten (Germany)

Katzenberger, Bernd
Landesanstalt für Umwelt, Messungen und Naturschutz BW (State Institute for Environment, Measurements and Nature Conservation Baden-Württemberg)
76231 Karlsruhe (Germany)

Kautz, Klaus
Wasser- und Schifffahrtsamt Dresden
(Waterways and Shipping Office Dresden)
01127 Dresden (Germany)

Kemper, Mike
76137 Karlsruhe (Germany)

Kemper, Tobias
TU Darmstadt, FG Umwelt- und Raumplanung
(Technical University Darmstadt, Department of Environment and Spatial Planning)
64287 Darmstadt (Germany)

Kempmann, Kai
Wasser- und Schifffahrtsamt Freiburg
(Waterways and Shipping Office Freiburg)
79104 Freiburg (Germany)

Kiehne, Klaus-Uwe
Wasser- und Schifffahrtsdirektion Süd
(Waterways and Shipping Directorate South)
97082 Würzburg (Germany)

Kieseleit, Holger
Ministerium für Bauen und Verkehr NRW
(Ministry for Construction and Transport of North Rhine-Westphalia)
40219 Düsseldorf (Germany)

Kindt, Hubert
Wasser- und Schifffahrtsdirektion Mitte
(Waterways and Shipping Directorate Center)
30169 Hannover (Germany)

Klar, Annika
Hamburg Messe u. Congress GmbH
20357 Hamburg (Germany)

Klein, Holger
Bundesamt für Seeschifffahrt und Hydrographie (Federal Maritime and Hydrographic Agency)
20359 Hamburg (Germany)

Klingen, Reinhard
Bundesministerium für Verkehr, Bau und Stadtentwicklung (Federal Ministry of Transport, Building and Urban Development)
53175 Bonn (Germany)

Kofalk, Sebastian
Bundesanstalt für Gewässerkunde
(Federal Institute of Hydrology)
56068 Koblenz (Germany)

Kohmann, Fritz
Bundesanstalt für Gewässerkunde
(Federal Institute of Hydrology)
56068 Koblenz (Germany)

Koldehofe, Wilhelm
Der Senator für Umwelt, Bau, Verkehr und Europa (Senator for Environment, Construction, Transportation and Europe)
28195 Bremen (Germany)

Kolokotronis, Vassilis
Landesanstalt für Umwelt, Messungen und Naturschutz BW (State Institute for Environment, Measurements and Nature Conservation Baden-Württemberg)
76231 Karlsruhe (Germany)

Koop, Friedrich
Wasser- und Schifffahrtsamt Magdeburg
(Waterways and Shipping Office Magdeburg)
39104 Magdeburg (Germany)

Köthe, Harald
Bundesministerium für Verkehr, Bau und Stadtentwicklung (Federal Ministry of Transport, Building and Urban Development)
53175 Bonn (Germany)

Kottmeier, Christoph
Institut für Meteorologie und Klimaforschung (Institute of Meteorology and Climate Research), Karlsruhe Institute of Technology
76128 Karlsruhe (Germany)

Kraft, Dietmar
ICBM-Terramare
26382 Wilhelmshaven (Germany)

Krahe, Peter
Bundesanstalt für Gewässerkunde
(Federal Institute of Hydrology)
56068 Koblenz (Germany)

Kröger, Martin
Zentralverband der deutschen Seehafenbetriebe e.V.
(Association of German Seaports Operators)
20457 Hamburg (Germany)

Krüger v. Marwick, Wolfgang
Bezirksregierung Köln
(District Government Cologne)
50667 Köln (Germany)

Lehfeldt, Rainer
Bundesanstalt für Wasserbau (Federal Waterways Engineering and Research Institute)
22559 Hamburg (Germany)

Leuchs, Wolfgang
Ministerium für Umwelt und Naturschutz, Landwirtschaft und Verbraucherschutz des Landes NRW (Ministry of the Environment and Conservation, Agriculture and Consumer Protection of the German State of North Rhine-Westphalia)
40476 Düsseldorf (Germany)

Lücking, Winfried
BUND-Flussbüro (River office of the League for the Environment and Nature Conservation, Germany)
10827 Berlin (Germany)

Ludwig, Andrea
Ministerium für Wirtschaft und Wissenschaft des Saarlandes (Ministry for Economics and Science of the Saarland)
66119 Saarbrücken (Germany)

Luhmann, Hans-Jochen
Wuppertal Institute for Climate, Environment and Energy
42103 Wuppertal (Germany)

Luijendijk, Bert
Port of Rotterdam,
3002 AP, Rotterdam (Netherlands)

Mahrenholz, Petra
Umweltbundesamt (Federal Environment Agency)
06844 Dessau (Germany)

Mai, Stephan
Bundesanstalt für Gewässerkunde
(Federal Institute of Hydrology)
56068 Koblenz (Germany)

Mandrup Thomsen, Randi
Royal Netherlands Embassy, Transport Department
0179 Berlin (Germany)

Manz, Werner
Bundesanstalt für Gewässerkunde
(Federal Institute of Hydrology)
56068 Koblenz (Germany)

Matulla, Christoph
Zentralanstalt für Meteorologie und Geodynamik (Central Institute for Meteorology and Geodynamics)
1190 Wien / Vienna (Austria)

Maurer, Thomas
Bundesanstalt für Gewässerkunde
(Federal Institute of Hydrology)
56068 Koblenz (Germany)

Mayer, Florian
Bundesamt für Naturschutz
(Federal Agency for Nature Conservation)
04277 Leipzig (Germany)

Mehling, Andrea
Bundesanstalt für Gewässerkunde
(Federal Institute of Hydrology)
56068 Koblenz (Germany)

Meine, Manfred
Hamburg Port Authority
20457 Hamburg (Germany)

Meßmer, Bernhard
Wasser- und Schifffahrtsdirektion Südwest
(Waterways and Shipping Directorate Southwest)
55127 Mainz (Germany)

Meyer, Marcus
Wasser- und Schifffahrtsdirektion Mitte
(Waterways and Shipping Directorate Centre)
30169 Hannover (Germany)

Möllenkamp, Sabine
Bundesministerium für Verkehr, Bau und Stadtentwicklung (Federal Ministry of Transport, Building and Urban Development)
53175 Bonn (Germany)

Morscheid, Harald
Bayerisches Landesamt für Umwelt
(Bavarian Environment Agency)
95030 Hof (Germany)

Moser, Hans
Bundesanstalt für Gewässerkunde
(Federal Institute of Hydrology)
56068 Koblenz (Germany)

Mudersbach, Christoph
University of Siegen (Germany)

Muilerman, Gert Jan
via donau – Österreichische Wasserstraßen-Ges.m.b.H
1220 Wien / Vienna (Austria)

Münch, Georg
Ministerium für Wirtschaft, Verkehr, Landwirtschaft
(Ministry for Economy, Transport and Agriculture)
55116 Mainz (Germany)

Nagel, Almut
Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (Federal Ministry of the Environment, Nature Conservation and Nuclear Safety)
53175 Bonn (Germany)

Namyslo, Joachim
Deutscher Wetterdienst
(German Meteorological Service)
20359 Hamburg (Germany)

Neukirchen, Bernd
Bundesamt für Naturschutz
(Federal Agency for Nature Conservation)
53179 Bonn (Germany)

Neumann, Lothar
Wasser- und Schifffahrtsamt Hamburg
(Waterways and Shipping Office Hamburg)
20148 Hamburg (Germany)

Niehoff, Daniela
Bundesamt für Bevölkerungsschutz und Katastrophenhilfe (Federal Office of Civil Protection and Disaster Assistance)
53127 Bonn (Germany)

Niehoff, Frank
Ministerium für Infrastruktur und Raumordnung des Landes Brandenburg (Ministry for Infrastructure and Regional Planning of the State of Brandenburg)
14467 Potsdam (Germany)

Nilson, Enno
Bundesanstalt für Gewässerkunde
(Federal Institute of Hydrology)
56068 Koblenz (Germany)

Oldewurtel, Ralph
Sächsisches Staatsministerium für Wirtschaft und Arbeit (Saxon State Ministry for Economic Affairs and Labour)
01097 Dresden (Germany)

Osenberg, Hans
Bundesministerium für Verkehr, Bau und Stadtentwicklung (Federal Ministry of Transport, Building and Urban Development)
10115 Berlin (Germany)

Pechan, Berthold
Ministerium für Landwirtschaft und ländliche Räume des Landes SH (Ministry of Agriculture and Rural Affairs of the State of Schleswig-Holstein)
24106 Kiel (Germany)

Petersen, Jörg
nature-consult
31139 Hildesheim (Germany)

Petersen, Volker
Ministerium für Landwirtschaft und ländliche Räume des Landes SH (Ministry of Agriculture and Rural Affairs of the State of Schleswig-Holstein)
24106 Kiel (Germany)

Polenz, Ines
Ministerum für Umwelt, Forsten und Verbraucherschutz (Ministry of Environment, Forestry and Consumer Protection)
5116 Mainz (Germany)

Prellberg, Dieter
Landesamt für Umwelt, Wasserwirtschaft und Gewerbeaufsicht RLP (State Office for Environment, Water Management and Trade Supervision in Rhineland-Palatinate)
55116 Mainz (Germany)

Reuter, Christian
HKV Hydrokontor GmbH
52068 Aachen (Germany)

Richter, Karl-Gerd
Wasserwirtschaft-Wasserbau GmbH
70133 Karlsruhe (Germany)

Rieken, Peter
PLANCO CONSULTING GmbH
45127 Essen (Germany)

Rist, Andreas
Ministerium für Landesentwicklung und Verkehr Sachsen-Anhalt (Ministry of Regional Development and Transport Saxony-Anhalt)
39114 Magdeburg (Germany)

Rodiek, Wilfried
Wasser- und Schifffahrtsdirektion Nordwest (Waterways and Shipping Directorate Northwest)
26603 Aurich (Germany)

Römer, Ulrich
Weather Online
53225 Bonn (Germany)

Rosenhagen, Gudrun
Deutscher Wetterdienst
(German Meteorological Service)
20359 Hamburg (Germany)

Rosenstein, Thomas
Bundesministerium für Verkehr, Bau und Stadtentwicklung (Federal Ministry of Transport, Building and Urban Development)
53175 Bonn (Germany)

Rothstein, Benno
University of Applied Forest Sciences – Rottenburg
72108 Rottenburg am Neckar (Germany)

Rubow, Dietlind
Ministerium für Umwelt und Naturschutz, Landwirtschaft und Verbraucherschutz des Landes NRW (Ministry of the Environment and Conservation, Agriculture and Consumer Protection of the German State of North Rhine-Westphalia)
40476 Düsseldorf (Germany)

Rudolf, Bruno
Deutscher Wetterdienst
(German Meteorological Service)
63004 Offenbach (Germany)

Rülke, Markus
Bundesministerium der Verteidigung
(Federal Ministry of Defence)
53123 Bonn (Germany)

Ruppert, Dieter
76133 Karlsruhe (Germany)

Rusche, Jörg
Bundesverband der Deutschen Binnenschifffahrt e. V.
(Federal Association of the German Inland Navigation)
47119 Duisburg (Germany)

Saha, Dieter Michael
International Commission for
the Protection of the Rhine,
56068 Koblenz (Germany)

Schleuter, Michael
Bundesanstalt für Gewässerkunde
(Federal Institute of Hydrology)
56068 Koblenz (Germany)

Schlurmann, Torsten
Franzius Institute
30167 Hannover (Germany)

Schmautz, Markus
RMD Wasserstraßen GmbH
80636 München (Germany)

Schmidt, Andreas
Bundesanstalt für Wasserbau (Federal Waterways Engineering and Research Institute)
76187 Karlsruhe (Germany)

Schneider, Carolin
Fachzentrum Klimawandel Hessen
(Hessian Centre on Climate Change)
65203 Wiesbaden (Germany)

Scholten, Anja
University of Würzburg
97074 Würzburg (Germany)

Scholz, Mathias
Helmholtzzentrum für Umweltforschung, Department Naturschutzforschung
(Helmholtz Centre for Environmental Research, Department of Conservation Biology)
04318 Leipzig (Germany)

Schoppmann, Heinrich
Wasser- und Schifffahrtsamt Schweinfurt (Waterways and Shipping Office Schweinfurt)
97422 Schweinfurt (Germany)

Schrenk, Georg
Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall (German Association
for Water, Wastewater and Waste)
53773 Hennef (Germany)

Schröder, Ulrich
IHP/HWRP Secretariat
56068 Koblenz (Germany)

Schroth, Susanne
Fachzentrum Klimawandel Hessen
(Hessian Centre on Climate Change)
65203 Wiesbaden (Germany)

Schuchardt, Bastian
BioConsult
28757 Bremen (Germany)

Schuster, Frank
RMD Wasserstraßen GmbH
80636 München (Germany)

Schüttrumpf, Holger
RWTH Aachen University, Chair and
Institute of Hydraulic Engineering and
Water Resources Management
52056 Aachen (Germany)

Schweighofer, Juha
via donau – Österreichische Wasserstraßen-Ges.m.b.H,
1220 Wien / Vienna (Austria)

Schweitzer, Stephanie
Wasser- und Schifffahrtsamt Rheine
(Waterways and Shipping Office Rheine)
48431 Rheine (Germany)

Seuser, Wolfgang
Chemical Industry Consulting
63828 Kleinkahl (Germany)

Söhngen, Bernhard
Bundesanstalt für Wasserbau (Federal Waterways Engineering and Research Institute)
76187 Karlsruhe (Germany)

Sommermeier, Knut
Staatliches Amt für Umwelt und Natur
(State Office for the Environment and Nature)
18059 Rostock (Germany)

Sprinzen, Manfred
Saaleverein, (Association for the enhancement of shipping on the River Saale)
06108 Halle (Germany)

Stadler, Jochen
University of Trier
54286 Trier (Germany)

Steege, Volker
Bundesministerium für Verkehr, Bau und Stadtentwicklung (Federal Ministry of Transport, Building and Urban Development)
53175 Bonn (Germany)

Stegemann, Gunter
Ingenieur-Kammer Bau NRW
(Chamber of Engineers in North Rhine-Westphalia)
53175 Bonn (Germany)

Steiner, Heiko
Deutscher Wetterdienst
(German Meteorological Service)
20359 Hamburg (Germany)

Stengel, Torsten
Wasser- und Schifffahrtsamt Bremen
(Waterways and Shipping Office Bremen)
28199 Bremen (Germany)

Stenglein, Jens
Wasser- und Schifffahrtsdirektion Südwest (Waterways and Shipping Directorate Southwest)
55127 Mainz (Germany)

Stribrny, Bernhard
Biodiversität und Klima Forschungszentrum
(Biodiversity and Climate Research Centre)
60325 Frankfurt (Germany)

Strotmann, Thomas
Hamburg Port Authority
20457 Hamburg (Germany)

Such, Wolfram
Deutsche Wasserhistorische Gesellschaft
(German Society for Water History)
53757 Sankt Augustin (Germany)

Täger, Henrik
Wasserstraßen-Neubauamt Magdeburg
(Waterways Construction Office Magdeburg)
39114 Magdeburg (Germany)

Tegtmeyer, Hans-Günter
Bundesministerium für Verkehr, Bau und Stadtentwicklung (Federal Ministry of Transport, Building and Urban Development)
53175 Bonn (Germany)

Tomassini, Lorenzo
Max Planck Institute for Meteorology
20146 Hamburg (Germany)

Törkel, Bernd
Bundesministerium für Verkehr, Bau und Stadtentwicklung (Federal Ministry of Transport, Building and Urban Development)
53175 Bonn (Germany)

Unger, Beate
Wasserstraßen-Neubauamt Magdeburg
(Waterways Construction Office Magdeburg)
39114 Magdeburg (Germany)

Van der Werf, Hans
Central Commission for the Navigation on the Rhine
67000 Strasbourg (France)

Völkl, Gesa
Wasser- und Schifffahrtsamt Brunsbüttel
(Waterways and Shipping Office Brunsbüttel)
25541 Brunsbüttel (Germany)

von Bargen, Uwe
Bremenports GmbH & Co. KG
27568 Bremerhaven (Germany)

von Storch, Hans
GKSS Research Centre
21502 Geesthacht (Germany)

Wachsmuth, Stephanie
Wasser- und Schifffahrtsdirektion Südwest
(Waterways and Shipping Directorate Southwest)
55127 Mainz (Germany)

Wagner, Michael
Hessischer Landesverband Motorbootsport
(Hessian powerboat racing association)
65191 Wiesbaden (Germany)

Wassermann, Stefanie
Bundesanstalt für Wasserbau (Federal Waterways Engineering and Research Institute)
76187 Karlsruhe (Germany)

Weber, Hans
Bayerisches Landesamt für Umwelt
(Bavarian Environment Agency)
95030 Hof (Germany)

Wempe, Michael
Wasser- und Schifffahrtsdirektion West
(Waterways and Shipping Directorate West)
48147 Münster (Germany)

Wetzel, Volkhard
Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall (German Association for Water, Wastewater and Waste)
53340 Meckenheim (Germany)

Wiesberg, Ingo
Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (Federal Ministry of the Environment, Nature Conservation and Nuclear Safety)
53175 Bonn (Germany)

Wild-Metzko, Sonja
Hamburg Port Authority
20457 Hamburg (Germany)

Wolf-Schumann, Uli
Hydrotec Ingenieurgesellschaft mbH
52066 Aachen (Germany)

Worreschk, Bernd
Ministerum für Umwelt, Forsten und Verbraucherschutz Rheinland-Pfalz (Ministry for Environment, Forestry and Consumer Protection of the State Rhineland-Palatinate)
55116 Mainz (Germany)

Zierul, Robert
Wasser- und Schifffahrtsdirektion Nord
(Waterways and Shipping Directorate North)
24106 Kiel (Germany)

Personal data

Paul Becker

Profile

Year of birth 1958

1980–1984
Degree in Meteorology
at the University of Hamburg

Since 2008
Head of the Business Area "Climate and Environment" and Member of the Executive Board of Directors at the German Meteorological Service (DWD)

1984–1989
Researcher at the University of Hamburg / Max Planck Institute for Meteorology

1987
Doctorate at the University of Hamburg

Since 1989
Civil servant at the German Meteorological Service (DWD)

2005–2008
Head of the Department "Medical Meteorology"

2006–2009
Head of the Department "Climate and Environment Consultancy"

Contact details

Dr. Paul Becker
Deutscher Wetterdienst
Frankfurter Straße 135
63067 Offenbach
Germany
Phone: +49 (0)69/8062-2972
Fax: +49 (0)69/8062-2959
E-mail: paul.becker@dwd.de

Jörg Uwe Belz

Profile

Year of birth 1960

1982–1988
Degree in Geography
at the University of Bonn

1988–1992
Executive partner of the "Gesellschaft für Angewandte Geowissenschaften" (GefaG) (association of applied geosciences), Bad Honnef (Germany)

Since 1992
Researcher at the Federal Institute of Hydrology (BfG), *Aufgabenbereichsleiter "Gewässerkundliche Analysen und Pegelwesen"* (Head of business area 'hydrological analysis and gauging')

Contact details

Dipl.-Geogr. Jörg Uwe Belz
Bundesanstalt für Gewässerkunde
Am Mainzer Tor 1, 56068 Koblenz
Germany
Phone: +49 (0)261/1306-5428
Fax: +49 (0)261/1306-5280
E-mail: belz@bafg.de

Wolfgang Bialonski

Profile

Year of birth 1947
Degree in Mechanical Engineering at the RWTH Aachen University in 1980, doctorate in Engineering in 1987 at the RWTH Aachen University

1980–1988
Project engineer at the Institute of Aerodynamics at the RWTH Aachen University

1988–1995
Project engineer at the Institute of Transport Science at the RWTH Aachen University, Group Leader Energy Consumption Group

Since 1996
Project engineer at the European Development Centre for Inland Navigation, now the DST-Entwicklungszentrum für Schiffstechnik und Transportsysteme e.V. (Development Centre for Ship Technology and Transport Systems)

Contact details

DST Entwicklungszentrum für
Schiffstechnik und Transportsysteme e.V.
Oststr. 77, 47057 Duisburg
Germany
Phone: +49 (0)203/9936953
Fax: +49 (0)203/361373
E-mail: bialonski@dst-org.de

Katharina Bülow

Profile

Year of birth 1968

1990–1996
Degree in Oceanography
at the University of Hamburg

1996
Researcher at the Leibniz Institute
of Marine Sciences at the University of Kiel

1997–2001
Researcher at the GKSS Research Centre Geesthacht GmbH

Since 2001
Researcher at the Max Planck Institute for Meteorology

Contact details

Katharina Bülow
Max-Planck-Institut für Meteorologie
Bundesstraße 53
20146 Hamburg
Germany
Phone: +49 (0)40/41173-382
E-mail: katharina.buelow@zmaw.de

Maria Carambia

Profile

Year of birth 1980

1999–2005
Degree in Civil Engineering at
the University of Karlsruhe

2005–2007
Researcher at the University of Kassel,
Department of Hydraulic Engineering and Water Resources Management

Since 2007
Researcher at the Federal Institute of Hydrology (BfG)

Contact details

Maria Carambia
Bundesanstalt für Gewässerkunde
Am Mainzer Tor 1
56068 Koblenz
Germany
Phone: +49 (0)261/1306-5491
Fax: +49 (0)261/1306-5280
E-mail: carambia@bafg.de

Helmut Fischer

Profile

1987–1994
Degree in Biology, majoring in Limnology, at the University of Freiburg

1996–2003
Researcher at the Leibniz Institute of Freshwater Ecology and Inland Fisheries (IGB), Berlin; Doctoral Thesis on "The abundance and production of bacteria in river sediments, and their relation to the biochemical composition of organic matter" (1996–2000)

2003–2005
Research fellowship at the Limnological Institute of the University of Uppsala, Sweden

Since 2005
Researcher at the Federal Institute of Hydrology

Contact details

Helmut Fischer
Bundesanstalt für Gewässerkunde
Am Mainzer Tor 1
56068 Koblenz
Germany
Phone: +49 (0)261/1306-5458
Fax: +49 (0)261/1306-5152
E-mail: helmut.fischer@bafg.de

Roy M. Frings

Profile

Year of birth 1979

1997–2001
Degree in Physical Geography
at the University of Utrecht

Since 2002
Researcher at the
University of Utrecht

Contact details

Dr. Roy M. Frings
Bundesanstalt für Gewässerkunde
Am Mainzer Tor 1
56068 Koblenz
Germany
Phone: +49 (0)261/1306-5987
E-mail: frings@bafg.de

Annegret Gratzki

Profile

Year of birth 1959

1978–1985
Degree in Meteorology
at the University of Cologne

1991
Doctorate in Meteorology
at the University of Cologne

1985–1987
Los Alamos National Laboratory, NM, USA

1988–1990
Institute of Geophysics and Meteorology,
University of Cologne

1991–1992
Internship (*Referendariat*) at German Meteorological Service (DWD)

1993–2007
Satellite remote sensing at German Meteorological Service

1999–2002
Head of work package in the project 'Satellite Application Facility on Climate Monitoring (CM-SAF)'

2003–2007
Head of Section (*Sachgebietsleiterin*); Coordination of scientific activities in the CM-SAF project

Since 2007
Head of the Hydrometeorological Consultancy Division
of the German Meteorological Service
Management of the KLIWA Project 1.01

Contact details

Dipl.-Met. Dr. Annegret Gratzki
Deutscher Wetterdienst
Frankfurter Straße 135
63067 Offenbach
Phone: +49 (0)69/8062-2989
Fax: 49 (0)69/8062-3987
E-mail: annegret.gratzki@dwd.de

Hartmut Heinrich

Profile

Year of birth 1952

1972–1977
Degree in Geology at the University of Göttingen

1983
Doctorate in Marine Biology at the University of Kiel
Work: 1983 Sand-gravel exploration in Schleswig-Holstein; as of 1983 at the Bundesamt für Seeschifffahrt und Hydrographie (Federal Maritime and Hydrographic Agency)

1983–1987
Sedimentology/Palaeoclimatology of the Northeast Atlantic

1988–1989
Sedimentoloy of the North Sea

1990–1993
TUVAS Project (Sea monitoring project for the North Sea)

1994–2005
Secretariat of the BLMP (Common Measurement Programme of the Federation and the Federal States) North Sea and Baltic Sea

Since 2005
Head of the Marine Physics Division with emphasis on climate monitoring

Contact details

Dr. Hartmut Heinrich
Bundesamt für Seeschifffahrt und Hydrographie
Bernhard-Nocht-Straße 78
20359 Hamburg
Germany
Phone: +49 (0)40-3190-3200
Fax: +49 (0)40-3190-5000
hartmut.heinrich@bsh.de

Michael Heinz

Profile

1978–1984
Degree in Civil Engineering at the Technical University of Darmstadt

1984–1986
Internship (*Referendariat*) at the Federal Waterways and Shipping Administration (WSV)

1986–1987
Wasser- und Schifffahrtsdirektion Süd (Waterways and Shipping Directorate South), Professional deputy (*Dezernent*), responsible for the Danube and Main-Danube Canal

1987–1990
New Construction Department for the development of the River Main, Head of section: river reaches and facilities (*Sachbereichsleiter für Strecken und Anlagen*)

1990–1992
Wasser- und Schifffahrtsamt Köln (Waterways and Shipping Office Cologne), Head of section (*Sachbereichsleiter*): waterways supervision, hydrology, surveying, property

1992
Wasser- und Schifffahrtsamt Duisburg-Rhein (Waterways and Shipping Office Duisburg-Rhine), Head of the WSV Wesel Outpost (*Leiter der Außenstelle Wesel*)

1992–2003
Federal Ministry of Transport, Building and Urban Development, *Referent für Technische Grundsatzangelegenheiten, Wasserstraßenmanagement Binnen sowie Controlling* (Desk Officer for Technical Policy Matters, Inland Waterway Management and Controlling)

Since 2003
Wasser- und Schifffahrtsdirektion West (Waterways and Shipping Directorate West), Head of Regional Management Department (*Leiter des Dezernates Regionales Management*)

Since 2006
In addition: Head of New Construction Department (*Leiter des Dezernates Neubau*)

Contact details

Michael Heinz
Wasser- und Schifffahrtsdirektion West
Cheruskerring 11, 48147 Münster, Germany

Harro Heyer

Profile

1974–1980
Degree in Geosciences

University career

1980–1981
Researcher at the Institute of Oceanography (Institut für Meereskunde) in Hamburg – development and application of models

1981–1987
Researcher at the University of Hanover
Fluid dynamics, development of simulation models, non-linear optimisation methods, electronic calculation in construction, doctorate

Activities at the Federal Waterways Engineering and Research Institute (BAW)

1987–1989
Researcher in the field of hydraulic engineering

1989–2003
Head of Section Technical Information Systems

1997–2003
Head of Section Estuary Systems

Since 2003
Head of the BAW Hamburg Office

Contact details

Dr.-Ing. Harro Heyer
Phone: +49 (0)40/81908-300
Fax: +49 (0)40/81908-373
E-mail: harro.heyer@baw.de

Berthold Holtmann

Profile

Year of birth 1962
Degree in Civil Engineering at the RWTH Aachen University
with specialisation in Transportation Studies; graduation in 1991

1991–1997
Traffic planning and consulting
for public transportation,
Spiekermann GmbH & Co., Düsseldorf

1997
Project engineer at the European Development Centre for Inland Navigation, now the DST-Entwicklungszentrum für Schiffstechnik und Transportsysteme e.V. (Development Centre for Ship Technology and Transport Systems)

1998–2004
Head of section "Transport Economics" at the European Development Centre for Inland Navigation, now the DST-Entwicklungszentrum für Schiffstechnik und Transportsysteme e.V. (Development Centre for Ship Technology and Transport Systems

2005–present day
Head of section "Transport Systems" at the DST Entwicklungszentrum für Schiffstechnik und Transportsysteme e.V. (Development Centre for Ship Technology and Transport Systems, Duisburg)

Contact details

Berthold Holtmann
DST Entwicklungszentrum für Schiffstechnik
und Transportsysteme e.V.
Oststr. 77,
47057 Duisburg
Germany
Phone: +49 (0)203/99 369 55
Fax: +49 (0)203/36 13 73
E-mail: holtmann@dst-org.de

Daniela Jacob

Profile

Year of birth 1961

1980–1986
Degree in Meteorology
at the TU (Technical University) Darmstadt

1986–1992
Doctoral thesis in Meteorology
at the University of Hamburg

Since 1993
Researcher at the Max Planck Institute for Meteorology in Hamburg

Since 2009
Extraordinary professor for "Regional Climate Change" at the University of Bergen, Norway (ancillary position)

Contact details

Dr. Daniela Jacob
Max-Planck-Institut für Meteorologie
Bundesstraße 53
20146 Hamburg
Germany
Phone: +49 (0)40-41173-313
E-mail: daniela.jacob@zmaw.de
Web: http://www.mpimet.mpg.de/institut/mitarbeiter/jacobdaniela/index.html

Reinhard Klingen

Profile

Year of birth 1955

1976–1981
Degree in Law
at the University of Bonn

2005–2009
Director of the Directorate Waterways at the BMVBS (Federal Ministry of Transport, Building and Urban Development)

since 2009
Director-General Waterways and Shipping at the BMVBS

Contact details

MDirig Reinhard Klingen
Unterabteilungsleiter Wasserstraßen
Bundesministerium für Verkehr,
Bau und Stadtentwicklung
Robert-Schuman-Platz 1
53175 Bonn
Germany
Phone: +49 (0)228/99-300-4400
Fax: +49 (0)228/99-300-4499
E-mail: al-ws@bmvbs.bund.de

Sebastian Kofalk

Profile

Year of birth 1963

1982–1990
Vocational training in agriculture, degree in Agricultural Sciences at the University of Göttingen

1991–1996
Researcher at the Institute for Ecology at the TU (Technical University) Berlin (Dept. of Soils Science / Site Ecology and Soil Protection)

1997
Doctoral thesis on mass and water balance in soils

1997–1999
Freelance work in the field of environmental planning

1999–2005
Federal Institute of Hydrology (BfG): coordination of a BMBF research programme, results synthesis and development of a decision support system

Since 2006
Department U2 "Ecological Interactions", preparation of the climate change initiative of the BMVBS

Since 2009
Chief coordinator for the KLIWAS research program of the BMVBS

Contact details

Dr. Sebastian Kofalk
Bundesanstalt für Gewässerkunde
Am Mainzer Tor 1
56068 Koblenz
Germany
Phone: +49 (0)261/1306-5330
Fax: +49 (0)261/1306-5333
E-mail: kofalk@bafg.de

Harald Köthe

Profile

Year of birth 1961

1981–1987
Degree in Geology at the University of Bonn

1988–2004
Federal Institute of Hydrology: researcher in Department M3 “Groundwater, Geology, River Morphology”

1998
Manager of the “Koordinationsstelle Baggergut” (coordination office for dredged material)

2003
Deputy head of Department G1 “General Water Quality Issues”

Since 2004
Federal Ministry of Transport, Building and Urban Development, Desk Officer (*Referent*) in the BMVBS Divisions EW 23 and WS 13 (technology, environmental protection and hydrology for federal waterways)

2006
Chairman of the Environmental Commission of PIANC (International Navigation Association)

2007
Desk Officer (*Referent*), Deputy Head of Division WS 14 (Climate, Environmental Protection, Hydrology for Waterways) of the BMVBS; amongst others initiation and supervision of KLIWAS

Contact details

Regierungsdirektor
Dipl.-Geol Harald Köthe
Bundesministerium für Verkehr,
Bau und Stadtentwicklung
Referat WS 14
Phone: +49 (0)228/300 4241
Fax: +49 (0)228/300 807 4241
E-mail: Harald.Koethe@bmvbs.bund.de

Peter Krahe

Profile

Year of birth 1958

1978–1985
Degree in Meteorology, Hydrodynamics and Geophysics at the Universities of Munich and Bonn

Since 1985
Researcher at the Federal Institute of Hydrology
Contact person for river basin modelling

Contact details

Dipl.-Met. Peter Krahe
Bundesanstalt für Gewässerkunde
Am Mainzer Tor 1
56068 Koblenz
Germany
Phone: +49 (0)261/1306-5234
Fax: +49 (0)261/1306-5280
E-mail: krahe@bafg.de

Stephan Mai

Profile

Year of birth 1968

1989–1995
Degree in Physics at the University of Bremen and collaboration at the Alfred Wegener Institute for Polar and Marine Research while studying

1995–2004
Work on interdisciplinary projects in climate impact research for coastal areas (e.g. KLIMU, KRIM) at the Franzius Institute of Hydraulics, Waterways and Coastal Engineering

1996–2000
Extra occupational degree in civil engineering at the University of Hanover

2001–2004
Doctoral thesis "Klimafolgenanalyse und Risiko einer Küstenzone am Beispiel der Jade-Weser-Region" (climate impact analysis and risk of coastal areas using the example of the Jade-Weser region) at the University of Hanover

Since 2005
Researcher in the Department M1 "Hydrometry and Hydrological Survey" at the Federal Institute of Hydrology

Coordinator for KLIWAS Task 2,
Climate change in coastal and estuarine areas, "Recording of changes in the hydrological system of the waterways".

Contact details

Dr.-Ing. Stephan Mai
Bundesanstalt für Gewässerkunde
Am Mainzer Tor 1
56068 Koblenz
Germany
Phone: +49 (0)261/1306-5322
Fax: +49 (0)261/1306-5383
E-mail: mai@bafg.de

Werner Manz

Profile

Year of birth 1963

1983–1989
Degree in Biology at the Technical University in Munich, course of studies in Biotechnology while pursuing a doctorate

1994
Doctoral thesis at the Department of Microbiology of the Technical University in Munich, research fellowship at the "National Bacteriological Laboratory" in Stockholm

1994–2001
Researcher and scientific assistant at the Technical University in Berlin, research visits at the "National Water Research Institute" in Saskatoon, Canada; Project Manager in externally funded projects in the field of microbial ecology of aquatic systems with a major emphasis on biofilm research

2001
Habilitation (post-doctorate qualification) at the Technical University in Berlin in the field of microbial ecology

Since 2005
Freelance lecturer (*Lehrbeauftragter*) for Ecotoxicology and *Privatdozent* for General Microbiology at the University of Koblenz-Landau

2002–2009
Director of Department G3 Bio-Chemistry / Ecotoxicology of the Federal Institute of Hydrology (BfG) in Koblenz

Since 2009
Professor for Microbiology at the University of Koblenz-Landau, Campus Koblenz, Institute of Integrated Natural Sciences, Dept. of Biology

Contact details

Prof. Dr. rer. nat. Werner Manz
Phone: +49 (0)261/287 2226
Fax: +49 (0)261/287 2222
E-mail: manz@uni-koblenz.de

Thomas Maurer

Profile

Year of birth 1963

1981–1989
Degree in civil engineering at the University of Karlsruhe,
specialisation in hydraulic engineering ("Wasserwesen")

1991–1997
Researcher at the University of Karlsruhe, doctorate

1998–2000
Björnsen Beratende Ingenieure, Hydroinformatics

Since 2000
Federal Institute of Hydrology (BfG)
2000–2005: Director of the Global Runoff Data Centre (GRDC)
2006: Head of Department: Geo-Information and Remote Sensing (M4)
Since 2007: Head of Department: Water Balance, Forecasting and Predictions (M2)

Contact details

Dr.-Ing. Thomas Maurer
Bundesanstalt für Gewässerkunde
Am Mainzer Tor 1
56068 Koblenz
Germany
Phone: +49 (0)261/1306-5242
Fax: +49 (0)261/1306-5671
E-mail: thomas.maurer@bafg.de

Hans Moser

Profile

Year of birth 1962

1983–1989
Degree in civil engineering at the University of Stuttgart

1990–1995
Researcher at the Institute of Hydraulic Engineering and Water Resources Management of the Technical University Berlin; doctorate

1995–2001
Management responsibilities in the field of federal waterways development and construction at the Federal Waterways and Shipping Administration (WSV)

2002–2004
Desk Officer (*Referent*) in the Division "Technology, Environmental Protection and Hydrology" at the Federal Ministry of Transport, Building and Housing; official residence in Bonn

Since 2004
Head of Division M "Quantitative Hydrology" at the Federal Institute of Hydrology (BfG) in Koblenz

Contact details

Dr.-Ing. Hans Moser
Bundesanstalt für Gewässerkunde
Am Mainzer Tor 1, 56068 Koblenz
Germany
Phone: +49 (0)261/1306-5303
Fax: +49 (0)261/1306-5280
E-mail: moser@bafg.de

Almut Nagel

Profile

1988–1995
Degree in Geography
at the Universities of Strasbourg and Trier

1996–2001
Professional experience in the fields of remediation of contaminated areas and environmental education

2002–2006
Providing support for German flood protection projects in the European Support Programmes INTERREG II C Rhine-Maas Activities (IRMA) and INTERREG III B

Since 2007
Desk Officer (*Referentin*) in the BMU, responsible for the coordination of the German Strategy for Adaptation to Climate Change (DAS)

Contact details

Dipl.-Geogr. Almut Nagel
Bundesministerium für Umwelt,
Naturschutz und Reaktorsicherheit
Robert-Schuman-Platz 3
53175 Bonn
Germany
Phone: +49 (0)229/99-305-2514
E-mail: almut.nagel@bmu.bund.de

Enno Nilson

Profile

Year of birth 1969

1992–1999
Degree in Geography, Geology, Soil Science and Forestry at the University of Bonn

1999–2001
Consultant for GIS, software engineering and databases for Unilog-Integrata Unternehmensberatung and Interactive Instruments GmbH

2001–2007
Researcher at the Department of Geography of the RWTH Aachen University, coordination of the project "The Ways of Water" (EU-Interreg IIIa)

2006
Doctorate in natural sciences (Dr. rer. nat.)

Since 2007
Researcher at the Federal Institute of Hydrology (BfG) Coordination of the KLIWAS project "Hydrology and Inland Navigation" (BMVBS)

Contact details

Dr. Enno Nilson
Bundesanstalt für Gewässerkunde
Am Mainzer Tor 1
56068 Koblenz
Germany
Phone: +49 (0)261/1306-5325
Fax: +49 (0)261/1306-5280
E-mail: nilson@bafg.de

Thomas Rosenstein

Profile

1994–2000
Degree in civil engineering
at the RWTH Aachen University

2000–2002
Internship (*Referendariat*) at the German Federal Waterways and Shipping Administration (WSV)

2002–2003
Waterways Construction Office (*Wasserstraßen-Neubauamt*) in Datteln, Project Manager

2003–2006
Waterways Construction Office (*Wasserstraßen-Neubauamt*) in Datteln, Head of Section for the upgrading of waterways (*Sachbereichsleiter für Streckenausbau*)

Since 2006
Federal Ministry of Transport, Building and Urban Development
Management of Inland Waterways (WS 11)
Desk Officer (*Referent*)

Contact details

Thomas Rosenstein
Referat WS 11
Bundesministerium für Verkehr,
Bau und Stadtentwicklung
Robert-Schuman-Platz 1
53175 Bonn
Germany

Benno Rothstein

Profile

Year of birth 1974

1995–2000
Degree in Applied Environmental Sciences at the University of Trier

2003
Doctorate (Dr. rer. nat.) in Geography/Geosciences at the University of Trier

Since 2007
Professor in **Resource Economics** at the University of Applied Forest Sciences Rottenburg

Since 2008
Course director for B.Sc. in BioEnergy

2008
Habilitation (post-doctorate qualification) at the Faculty "Arts I" of the Julius-Maximilians University at Würzburg; *Habilitationsschrift* (professorial dissertation): "Elektrizitätswirtschaft als Betroffene des Klimawandels – Eine Identifikation von Betroffenheiten und Ansätze zur Anpassung an den Klimawandel dargestellt am Beispiel der Energieunternehmen EnBW und EDF" (Impacts of climate change on electricity resource management – Identification of impacted areas and approaches for adaptation to climate change, using the example of the energy suppliers EnBW and EDF); qualification as university professor (*Lehrbefähigung* – *facultas docendi*) in geography.

Contact details

Prof. Dr. Benno Rothstein
Hochschule für Forstwirtschaft Rottenburg
Schadenweilerhof
72108 Rottenburg
Germany
Phone: +49 (0)7472/951 249
Fax: +49 (0)7472/951 200
E-mail: rothstein@hs-rottenburg.de

Bruno Rudolf

Profile

Year of birth 1948

1969–1974
Degree in Meteorology at the University of Bonn

1975–1976
Internship (*Referendariat*) at the German Meteorological Service (DWD)

1977–1989
Department of Climatology at the DWD; development and application of mesoscale models in the field of urban climate and environment; collaboration in the commission on radiological protection and on waste heat

1989–2006
Director of the World Centre for Precipitation Climatology; since 1995 Head of the Section "International Data Centres"

1995
Doctorate at the University of Hanover in Meteorology and Hydrology

Since 2006
Head of the Hydrometeorology Department of the German Meteorological Service
Coordinator of KLIWAS Task 1

Contact details

Dipl.-Met. Dr. Bruno Rudolf
Deutscher Wetterdienst
Frankfurterstraße 135
63067 Offenbach
Phone: +49 (0)69/8062-2765
Fax: +49 (0)69/8062-3987
E-mail: bruno.rudolf@dwd.de

Andreas Schmidt

Profile

Year of birth 1957

1978–1986
Degree in civil engineering with specialisation in Hydraulic Engineering (*Wasserwesen*) at the RWTH Aachen University, and in Engineering Hydrology at Imperial College of Science and Technology, London

1986
Researcher at the Institute of Hydraulic Engineering and Water Resources Management / field of teaching: water energy at the RWTH Aachen University

1986–1993
Researcher at the Institute of Hydraulic Engineering and Water Resources Management of the TU (Technical University) Berlin; doctorate

1993–1999
Federal Institute of Hydrology (BfG), Berlin Local Office; Head of area "River Morphology"

Since 1999
Federal Waterways Engineering and Research Institute (BAW), Karlsruhe
1999–2003: Head of Section "River Systems II"
2003–2008: Head of Section "River Systems I"
Since 2008: Head of Department "Hydraulic Engineering in Inland Areas"

Contact details

Dr.-Ing. Andreas Schmidt
Bundesanstalt für Wasserbau
Kußmaulstr. 17
76187 Karlsruhe
Germany
Phone: +49 (0)721/9726-3010
Fax: +49 (0)721/9726-2610
E-mail: andreas.schmidt@baw.de

Anja Scholten

Profile

1999–2004
Degree in Meteorology at the Rheinische Friedrich-Wilhelms-University of Bonn

2005–2007
Project assistant at the Wuppertal Institute for Climate, Environment and Energy

Since 2007
Researcher at the Julius-Maximilians-University of Würzburg

Contact details

Dipl.-Met. Anja Scholten
Universität Würzburg
Physische Geographie
Am Hubland
97218 Würzburg
Germany
Phone: +49 (0)931/318 5435
E-mail: anja.scholten@uni-wuerzburg.de

Jens Stenglein

Profile

1969–1975
Degree in civil engineering at the Technical University of Berlin

1976–1978
Researcher at the Federal Institute of Hydrology (BfG) in Koblenz

1978–1980
Internship (*Referendariat*) at the German Federal Waterways and Shipping Administration (WSV)

1980–1982
Head of Hydrology (*Gewässerkunde*) at the Wasser- und Schifffahrtsamt (Waterways and Shipping Office) Hamburg

1982–1986
Head of section (*Sachbereichsleiter*) "Waterways supervision, hydrology, surveying and property" at the Waterways and Shipping Office (Wasser- und Schifffahrtsamt) Kiel-Holtenau

1986–1989
Head of section (*Sachbereichsleiter*) "Waterways supervision, waterway signs, navigation, surveying and property"

1989–1993
Desk Officer (*Referent*) at the Federal Ministry of Transport with responsibility for organisation of the WSV

1993–1999
Director of the Waterways and Shipping Office (Wasser- und Schifffahrtsamt) Koblenz

Since 1999
Director of the Regional Management Department at the Waterways and Shipping Directorate Southwest (Wasser- und Schifffahrtsdirektion Südwest) in Mainz

Since 2003
Vice President of the Waterways and Shipping Directorate Southwest (Wasser- und Schifffahrtsdirektion Südwest) in Mainz

Contact details

Jens Stenglein
Wasser- und Schifffahrtsdirektion Südwest
Brucknerstr. 2
55127 Mainz
Germany
Phone: +49 (0)6131 / 97 94 01
E-mail: jens.stenglein@wsv.bund.de

Lorenzo Tomassini

Profile

Year of birth 1969

1990–1997
Degree in Mathematics at the ETH (Swiss Federal Institute of Technology) Zurich

1998–2002
Doctorate in Mathematics at the ETH Zurich

2002–2003
Postdoctoral fellow at Northwestern University, Chicago, USA

2004–2007
Doctorate in Environmental Sciences at the ETH Zurich

Since 2008
Researcher at the Max Planck Institute for Meteorology

Contact details

Lorenzo Tomassini
Max-Planck-Institut für Meteorologie
Bundesstraße 53
20146 Hamburg
Germany
Phone: +49 (0)40-41173-205
E-mail: lorenzo.tomassini@zmaw.de

Bernd Törkel

Profile

Year of birth 1948

1968–1972
Degree in Economic Sciences at the University of Kiel

2007–2009
Director-General Waterways and Shipping at the BMVBS (Federal Ministry of Transport, Building and Urban Development)

Hans von Storch

Professor von Storch has been Director of the Institute of Coastal Research at the GKSS Research Centre and Professor at the Meteorological Institute of the University of Hamburg since 1996.

His research interests include coastal climate and its effects (wind, storm tides and waves). He became well-known, among others, for his comprehensive text book "Statistical Analysis in Climate Research" and his collaboration with social scientists.

Professor von Storch has been involved in interdisciplinary research for many years. He has published 13 books and numerous articles and has been appointed to many honorary posts, such as membership of the steering committee of the Centre of Excellence KlimaCampus in Hamburg. He has received many scientific awards.

He studied mathematics, physics and Danish at the University of Hamburg, graduating in the year 1976. He completed his doctorate in 1979 and his post-doctorate thesis ("*Habilitation*") in 1985. He then worked at the Max Planck Institute for Meteorology. In October 2008, he was awarded an Honorary Doctorate by the University of Göteborg.

Contact details

Prof. Hans von Storch
Institute for Coastal Research,
GKSS Research Center
http://coast.gkss.de/staff/storch
Tel.: + 49-171-2 12 20 46
Fax: + 49-415-28 74 18 31
E-mail: hvonstorch@web.de