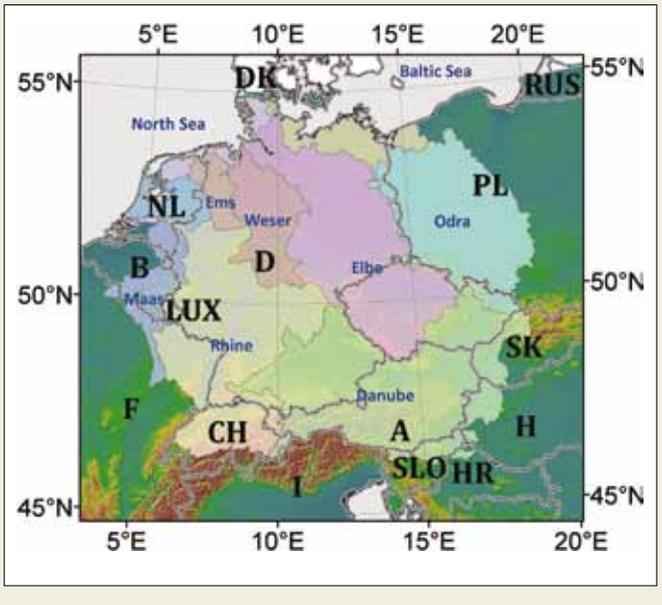
An integrated climate service for the transboundary river basin and coastal management of Germany

By Professor Dr H Moser, Dr J Cullman, Dr S Kofalk, Dr S Mai and Dr E Nilson, Federal Institute of Hydrology, Germany; and S Rösner, Dr P Becker, Dr A Gratzki and K-J Schreiber, German Meteorological Service

All infrastructure planning in water resources management, waterways engineering, flood protection, and coastal defence requires knowledge of meteorological, hydrological and oceanographic parameters on a climate scale. Since the planning horizon of such infrastructure projects spans from decades to a century and beyond, information about historical and future climate changes is of utmost relevance.

The KLIWAS programme (KLIWAS — Impacts of climate change on waterways and navigation - Searching for options of adaptation) provides an integrated climate information service for trans-boundary river basin and coastal management in Germany. It was initiated as a contribution to the German Strategy for Adaptation to Climate Change[1]. The KLIWAS initiative provides climatological data and assesses climate impacts for the following sectors: water regime, water resources management; coastal and marine protection; biological diversity; fishery; and transport, transport infrastructure. KLIWAS serves as a knowledge base for stakeholders, like the Federal Waterways and Shipping Administration, and for all others concerned with one of these sectors. The activity is coordinated by the German Federal Institute of Hydrology on behalf of the German Ministry of Transport, Building and Urban Development. It is closely linked to services provided by the German Meteorological Service.



The focus areas for KLIWAS work are the basins of the rivers Rhine, Danube and Elbe and the coastal areas of the North Sea

Source: BfG

Identifying the user needs and expectations of the water sector

The outcome of the departmental climate related hydrological and oceanographical service is driven by stakeholders involved in river basin and coastal management. To identify the stakeholders, water authorities from inside and outside Germany are informed, for example through the direct involvement of KLIWAS in international river commissions or through organisation of regular meetings with politicians, water managers and waterway users (such as KLIWAS Status conferences and KLIWAS stakeholder workshops).

We used experiences and a common understanding built by the implementation of the European Water Framework Directive (EU-WFD). The EU-WFD summarizes much of the European experience on pollution, water quality and ecosystem management, and it represents a comprehensive way to ensure that there is enough clean water for different uses, and to avoid disasters like flooding and droughts. Besides there are existing traditional responsibilites and roles within the framework of water management in a federal organized state, with its decision and participation processes which are also used to set up our climate services.

Stakeholders (including the European Commission, the Federal Ministry of Transport, Building and Urban Development and its Waterways and Shipping Administration, several other Federal Government and federal state ministries and their executive agencies, representatives from shipping, ports and industry consulting engineers, water management, environmental protection, nature conservation, and academia, primarily from the field of climate change impact research) are in contact with the KLIWAS consortium to fulfil their needs for climate change related information raised by the latest IPCC asessment report[2]. Existing participation

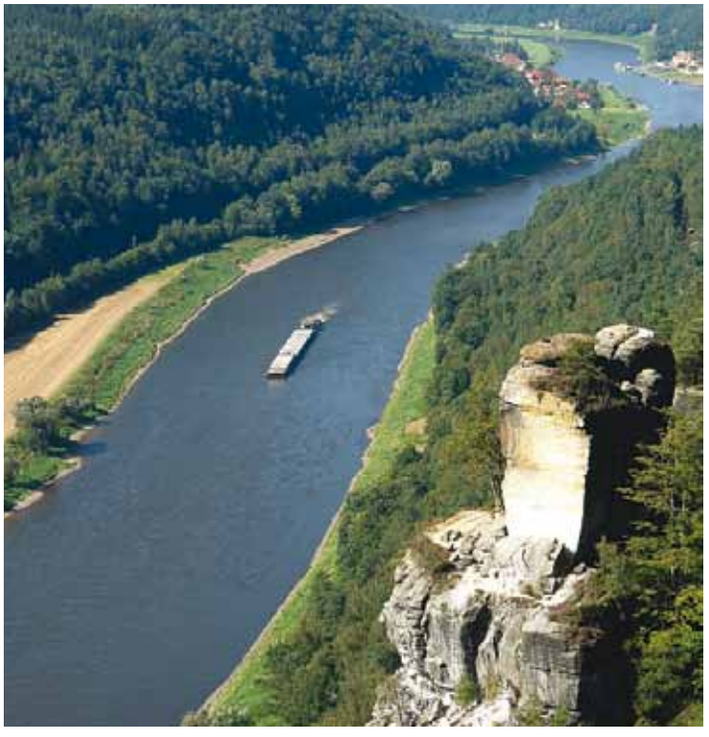


Image: Fritz Kohmann/BfG

Pushed convoy sailing on the Elbe river near Dresden

processes are used; for example through international river commissions and working groups.

Users of the services on an operational level of management prepare decisions in policy development and economy and define at the end which information or data for which analyses and which decisions have to be designed as service products.

The outcome of reiterated meetings with users led to a set of indicators by which we characterise climate change and impacts e.g. projections for discharges etc.

With respect to the service products, the following general user expectations were identified:

- *A sound scientific approach has to be the basis for the model derived products:* The multi-model approach of KLIWAS is the scientific approach in climate change impact research.
- *A clear concept of the evaluation facilitates the application of the results:* KLIWAS has designed a general evaluation framework for climate impact research. This includes quality criteria for model data, defined spatial and temporal resolutions of data products and specific statistical measures for different user groups.
- *The multi-sectoral interests in water management have to be integrated into the approach:* We reached this by integration of multi-diciplinary model chains (climate, water quantity, -quality, -ecology, engineering, and economic aspects). This means to build up a scale-consistent prognostic model chain and defined clear workflow between partners to reach an operational level in our climate services.
- *The data and information products have to be available and easily applicable:* For this reason we implemented web-based distribution channels via our portals, matching international standards of data-management.
- *Accompanying documents concerning certainty and uncertainty of climate projections have to be provided to support the users.* Uncertainty guidance forms a core element of all KLIWAS documents.

Identifying the institutional framework

The institutional framework of KLIWAS was built upon the competences of the agencies responsible and able to offer services related to relevant management questions. If additional know-how is required, third parties are being involved.

Together the association of the National Meteorological Service of Germany (DWD), the German Maritime and Hydrographic Agency (BSH), the German Federal Institute of Hydrology (BfG) and the German Federal Waterways Engineering and Research Institute (BAW) offered these competences in form of the KLIWAS research programme. The Federal Ministry of Transport, Building and Urban Development financed the programme — comprising 31 projects — with an initial lifetime of five years (starting in 2009) and a budget of four million euros per year. These funds are invested to set up a climate service on a longer perspective; after 2013 the service is intended to continue operationally. The funding of the services is completed and supplemented by other research funds, for example from the Seventh European Framework Programme and the German Federal Ministry of Education and Research.

KLIWAS is based on data, methods and models, generated not only by the four governmental institutes (DWD, BfG, BSH and BAW) but by a network of institutions (such as the hydrological and meteorological services of Germany and the neighbouring countries). This integrated approach is regarded as a key concept to provide information that is based on the state of the art of knowledge. Data products are presented and discussed in national and/or international expert groups before they are offered to stakeholders and for further application. This feedback is essential for the transparency, reliability and thus for the acceptance of the KLIWAS services and products. Use of KLIWAS products outside of the KLIWAS community follows the data policy of the institutes which participate in the KLIWAS research program. Hydrological services are free of cost.

From an organisational point of view the top level of the institutes has a monitoring role and evaluates the results — in close cooperation with the financing ministry — with respect to general strategic questions. Decisions on the operational level are made by the responsible project managers together with the users of our services and scientific partners.

Data and models

The meteorological and hydrological data and models of KLIWAS are linked in a complex model chain which mimics the complex structure of the system under investigation, namely the major river systems and the coastal areas of Germany and the neighbouring countries. At each link of the chain multiple models are involved to give an idea of the uncertainty associated with each modelling step.

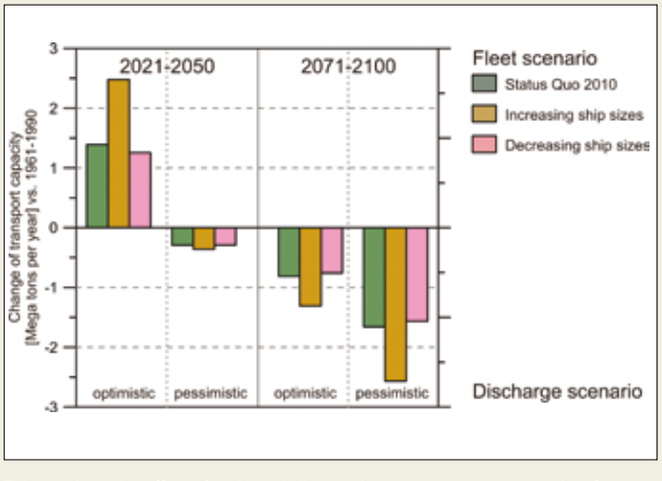
In the framework of KLIWAS DWD acquires climate model output from global and regional climate models from various research groups. The

model data are then further processed for the use in KLIWAS impact models. This post-processing includes the verification of control runs, the statistical analysis of the future climate projections, further downscaling of regional climate model output by means of statistical methods and the bias correction of model output. In addition, DWD compiles and generates meteorological reference data sets for the entire international basins of the rivers under investigation, as well as for the North Sea, the Baltic Sea, and the adjacent North Atlantic. The reference data sets support the verification of climate model data and KLIWAS impact models as, for example, hydrological models, and are used for the bias correction of climate model output.

At BfG and BSH the simulated and observed meteorological data are used as input for hydrological and oceanographic models to assess the impact of climate variability on stream flows, sea level etc. The climate model data are bias-corrected to be applicable in the impact models. Also here, multiple correction methods are compared to demonstrate the specific modifications of model results.

Methods and (hydrological) models are set up and/or evaluated in cooperation with water research institutes and water managers working on the same river basins as KLIWAS. All institutions and persons bring in their own hydrological expertise and data. For example, the model used for short term forecasts is used in the same version in Germany and the Netherlands. Thus, the quality of the models and data is double-checked and consistent across the border.

The KLIWAS programme does not end with information on water quantity and hydrodynamics. It also tailors specific information for different user groups. For example, further models are coupled to assess and monetize the effects of climate and hydrological change on inland waterway transport. Specific information on future transport costs and capacities under climate change conditions are offered – including an uncertainty statement. Using this information, the users (for example, the BAW) evaluate adaptation measures such as innovative steering techniques for the vessels travelling on the River Rhine.



This graph on the effect of projected climate change on transport capacity of cargo on the Rhine river is an example of user-specific information generated by KLIWAS

Source: Development Centre for Ship Technology and Transport Systems

Example service: discharge scenarios for policy development

As a consequence of the close stakeholder involvement, information provided by KLIWAS is already in use in policy development. For example, in 2010 KLIWAS and network partners agreed on a general evaluation framework designed to select and process climate model data for the purpose of impact modelling.[3] This procedure resulted in a reduced ensemble (20 out of 26 members) of bias corrected climate simulations, which are regarded as suitable for hydrological modelling. On that basis a set of hydrological indicators was generated, which characterises the potential future hydrological regimes of the River Rhine in the middle and the end of the 21st century. The indicators were chosen to meet the user needs that were identified; i.e. they indicate a bandwidth of results for relevant hydrological statistics given the current modelling uncertainty as sampled by an ensemble of quality checked and bias corrected climate simulations. This work was coordinated, documented and published online by the International Commission for the Hydrology of the Rhine basin (CHR).[4]

The indicators were discussed by the International Commission for the Protection of the Rhine (ICPR), an advisory board that coordinates the work of representatives of the governments of Switzerland, France, Germany, Luxemburg, Netherlands and the European Commission. Guidance on how to read the indicators was given during specific workshops for representatives dealing with floods, ecology, sediments and strategic questions. In 2011, the ICPR members adopted the indicators as scenarios to prepare the development of forward looking, sustainable water management adjustment strategies to floods, ecology and water quality.

The data and the documentation on the ICPR scenarios are now accessible online in four languages (English, French, Dutch, and German) via the ICPR website.[5] This information is increasingly accepted and used. For example, the inland navigation sector as organised in the Central Commission for the Navigation of the Rhine takes the same values as basis for an assessment for adaptation needs.[6]

Example service: WAVOS daily low flow forecast

Within the integrated modelling system of the institutes forming the KLIWAS consortium, not only centennial projections but also daily forecasts are offered. The latter is implemented as an operational online service, named WAVOS.

Currently, the service covers lead times up to four days for selected gauges along several major rivers in Central Europe (Rhine, Elbe, Upper Danube, Oder). One purpose of the daily forecasts is to support the transport and logistics sector along the rivers when vessel operations may be restricted due to extreme flow conditions. But also other users benefit from this service, for example, the flood centres of the German federal states.

The service is based on a comparable model chain as the climate service – starting from meteorological model output, which is optimised to be applicable in hydrological and hydrodynamic models. The forecasting system takes weather forecasts of the German Meteorological Service as input. The initialisation is based on station data retrieved from DWD and the French Meteorological Service (Météo-France).

These data are assimilated into the hydrological and hydrodynamic components which are run at BfG. At the end of the processing chain, stream flow and water level information is offered for relevant gauges on the waterways. The forecasts are updated daily. They are accessible free of charge via the internet and videotext. Up to 4,000 clicks per day on the website indicate the high level of acceptance of the service.

Lessons learned

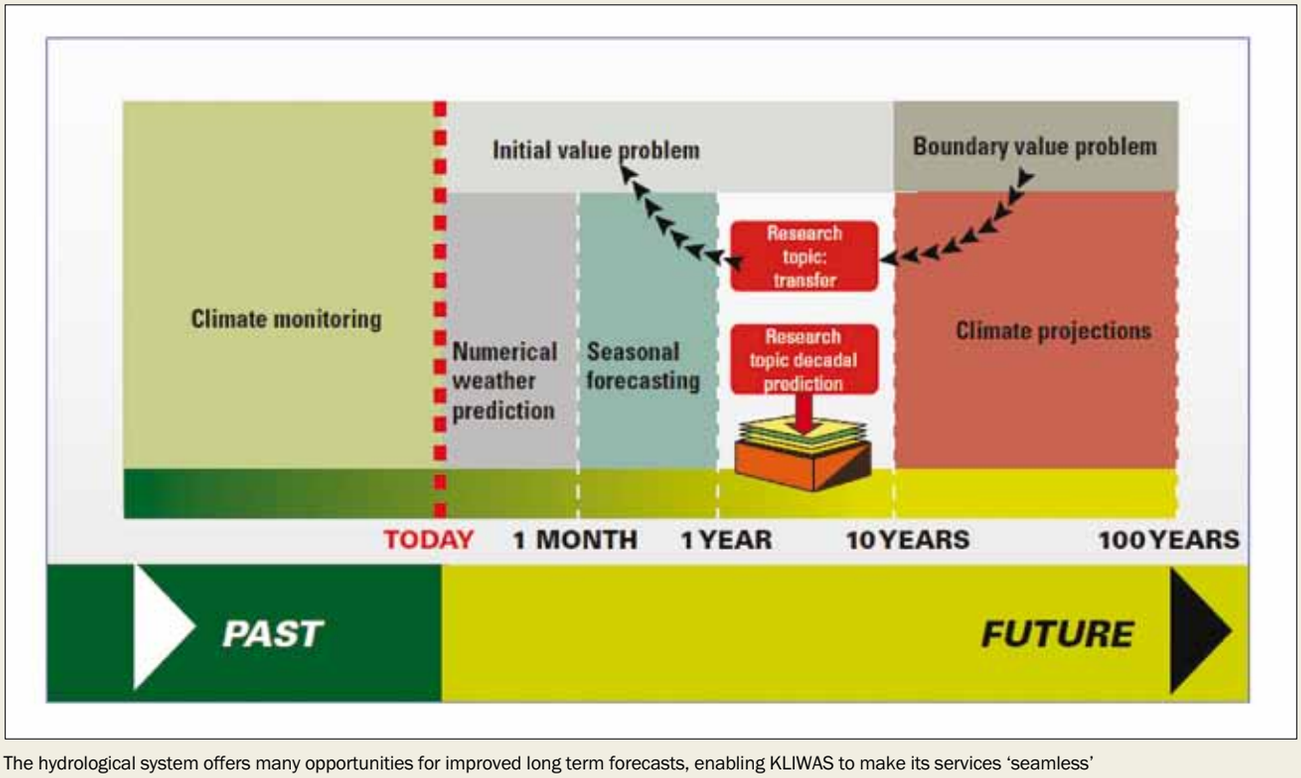
The processing framework and scientific network of KLIWAS gives information on climate change and climate impacts that is quantitative, is tailored for relevant environmental and economic sectors, includes uncertainty guidance that has proven to be comprehensible for stakeholders and is widely accepted in science and administration due to early coordination with scientific institutions working in the same area and field. However, it is dependent on the current capability of complex model chains to resemble real world phenomena, and on the availability and quality of observed data on all components of the water balance.

KLIWAS continues to work on the improvement of data and models and on the dissemination of results. Currently, an integration of many data and models is regarded as best choice to obtain relevant information on climate change and climate impacts.

With the current human, infrastructural, institutional and procedural capacities, KLIWAS has reached a service level that is acceptable for many users. The evaluation framework is particularly appreciated. For example, the Water director of Germany concludes, that "KLIWAS breaks new methodical ground as a pioneer and pathfinder towards the establishment of a multi-model approach. The representation of the spans of possible projections provides a new quality for climate risk assessment to decision makers."[7]

However, a higher service level is still conceivable and would help to support additional user groups with more specific information. For example, technical improvements like advanced data exchange portals could help to push data faster through the model chain. This could set resources free for additional post processing steps, more in-depth data evaluation, and individual user support. In addition, the coherency of the presentation of the different services could be improved.

A topic already scheduled by KLIWAS is the improvement of the seasonal to decadal prediction capabilities. In addition to the work on the medium range weather forecasts, the hydrological system offers many opportunities here through its slow components (snow and groundwater storage). These will be exploited in the coming years, making the KLIWAS services 'seamless'.



The hydrological system offers many opportunities for improved long term forecasts, enabling KLIWAS to make its services 'seamless'

Source: DWD