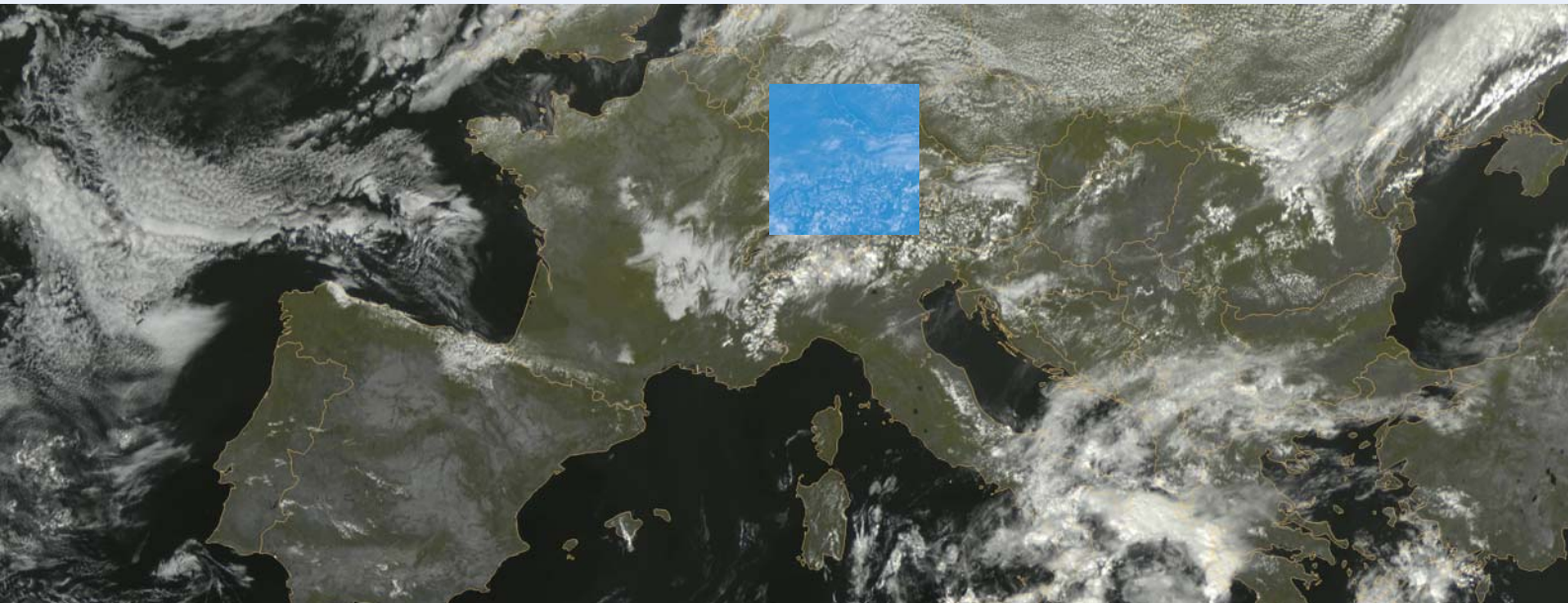


Climate Change in Southern Germany

Extent – Consequences – Strategies



IMPACT ON WATER RESOURCES MANAGEMENT



Rheinland-Pfalz

MINISTERIUM FÜR
UMWELT, FORSTEN UND
VERBRAUCHERSCHUTZ



Baden-Württemberg

UMWELTMINISTERIUM

Bayerisches Staatsministerium für
Umwelt und Gesundheit



Deutscher Wetterdienst



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FOREWORD

Water is one of the most valuable gifts of nature. We all live by water and with water. Water management carries a heavy load of responsibility. On the one hand it must ensure that water functions as the indispensable foundation of life, on the other it must protect people against the potential threat that it represents. Standards of water management in Germany are high. We are protecting our waters and improving them wherever necessary. We have sufficient good quality drinking water, and we are investing millions in flood protection.

But the water cycle is in a state of flux. With climate change, our water resources are changing as well. We know today that temperatures are rising all over the world as a result of the greenhouse effect, and this process is set to continue. We will no longer be able to halt these developments, but we must try to keep the effects of the changes under control with the help of a consistent and effective climate protection strategy.

As a consequence of climate change, we must anticipate an increase in the incidence of extreme weather events. In all probability the future will see more frequent heavy rainstorms, but there are also likely to be more heatwaves and periods of drought. Water management must adapt accordingly, and try to find new ways of coping with these developments.

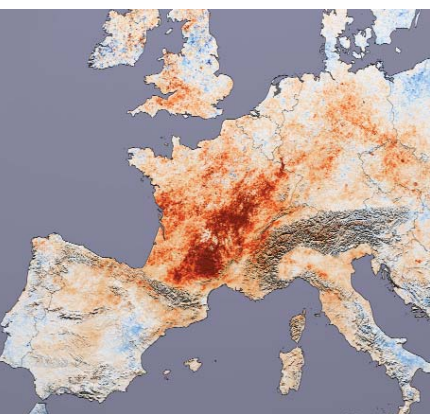
Thanks to KLIWA we are now in a position to estimate approximately how climate change will affect flooding, low water and our groundwater reserves. Of course there continue to be some grey areas. We must evaluate these accurately while setting the points correctly for the future, and this is a major challenge. But even in terms of fundamentals there is a need for action. How will climate change affect the water quality of our streams and rivers? What adjustments may turn out to be necessary?

A consistent climate protection strategy, at global, national and regional levels, will enable us to keep the consequences of climate change within calculable limits. The emission of greenhouse gases must be checked as far as possible. Where the effects can no longer be reversed, we must respond by making the necessary adjustments. This means preparing climate-sensitive systems for the changes in the best possible way. To ensure that this happens, the adaptability of our ecosystems must be increased and their vulnerability reduced, and we must go on consistently extending our current pool of expert knowledge on climate change and its consequences. The KLIWA cooperative project is making an important contribution in this connection.



Increasing incidence of weather extremes: is our climate going berserk?

The start of the 1990s saw a sharp increase in extreme weather conditions in our country. In 2003, Europe suffered for weeks from temperatures of as much as 40 °C; in August 2005, following extreme and persistent rain, the Alpenvorland [Alpine Foothills] reported that it had been completely submerged. Winter 2007/2008 had temperatures that were almost like spring at times, but the following winter was exceptionally harsh. All the same, the year 2008 proved to be one of the ten hottest since the beginnings of meteorological records. Is this combination of circumstances just coincidence, or is it an indication that climate change is already in full swing?



Extreme weather in the summer of 2003: heatwave in Central Europe (especially in the red areas)

... OR ARE THESE QUITE NORMAL VAGARIES OF THE WEATHER?

In the course of millennia, the earth's climate has always been exposed to natural fluctuations. At times Europe enjoyed a tropical climate, at others massive ice sheets burdened the earth. Sediment drill samples and pollen analysis yield insights about climate fluctuations in early phases of the earth's history. Since 1860 weather data has been recorded on a regular basis. When this is evaluated, we find that the global average temperature has risen by around 1 °C over the last 150 years. That does not sound like a large amount – but it makes you think, when you reflect that in the last Ice Age the temperature on earth was only 4-5 °C cooler than it is now.

GREENHOUSE EARTH

The pleasant global average temperature of +15 °C is a phenomenon for which we can thank the natural greenhouse effect. Trace gases that occur in the earth's atmosphere, like water vapour, carbon dioxide and methane, have the same effect as the glass panes of a conservatory. They allow short-wave sunbeams to penetrate and to some extent restrict the reverse emission of long-wave heat radiation. That is why they are called greenhouse gases. Without the natural greenhouse effect, average temperatures would be around –18 °C and incapable of supporting life.

Since the start of industrialisation, the carbon dioxide content of the atmosphere, which had remained relatively constant at 280 ppm (parts per million) in preceding centuries, has been rising. 385 ppm is the current reading. This greenhouse effect, which is caused by human beings, is having an effect on the water cycle at both global and regional levels.

THE KLIWA PROJECT

Are the extreme weather conditions and flood catastrophes of recent years already the heralds of climate change? How are the climate and our water resources likely to change – and how can we respond to these developments?

To investigate these questions, in December 1998 the federal states of Baden-Württemberg and Bavaria, in association with Deutscher Wetterdienst [German Weather Service], set up the cooperative project 'Klimaveränderung und Konsequenzen für die Wasserwirtschaft' ['Climate Change and its Impact on Water Resources Management'], or KLIWA for short. The federal state of Rhineland-Palatinate also joined the partnership in 2007.

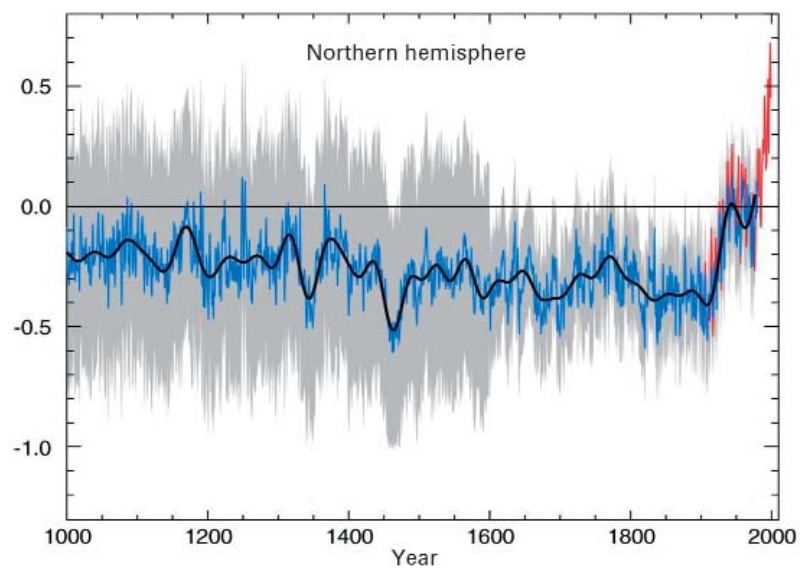
The object of this cross-regional interdisciplinary partnership project is to work out the possible impact of climate change on the water resources of riverine areas in the south of Germany, highlight the probable consequences and develop recommendations for action. Up to the present time the KLIWA project has already achieved substantial results. First of all, meteorological and hydrological records in the south of Germany were analysed and trends established on that basis. In reliance on this data, future climatic conditions have been estimated for the period 2021-2050, with selected regional climate projections. This future climate data was then fed into finely meshed water management models for the various riverine areas. The topics investigated were as follows: flooding, groundwater, low water, soil erosion and water quality. To some extent concrete recommendations for action are already being formulated.

KLIWA ON THE WEB

Further information about the KLIWA project may be found at the project website on www.kliwa.de. In the download area you will find detailed reports and publications about the project's results and working methods to date.

TEMPERATURE DEVELOPMENTS IN THE NORTHERN HEMISPHERE

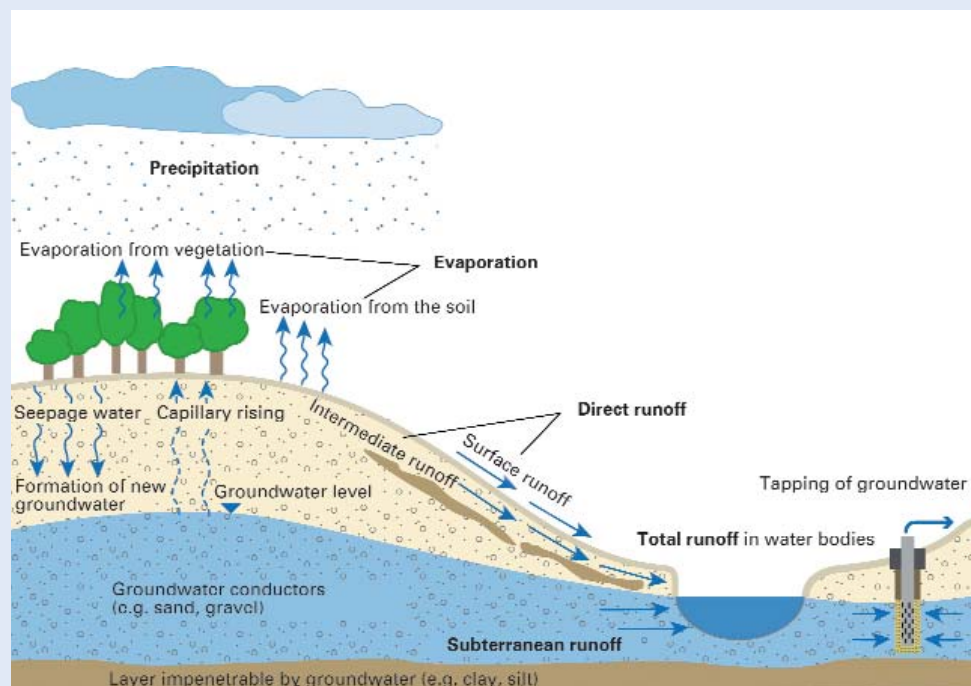
The diagram shows the deviation of the annual mean temperature from the average temperature based on the long-term mean for the period 1961 to 1990. At the start of the 20th century, the climate in the northern hemisphere began to heat up to a significant extent. This development has speeded up considerably in recent decades.



Source: IPCC 2001

THE WATER CYCLE

Two thirds of the earth's surface is covered with water. Part of the water circulates round the globe in a massive cycle, in the form of vapour, liquid or ice. Water that evaporates from the earth's surface rises into the atmosphere as water vapour, condenses into clouds and falls back to earth as rain or snow. This precipitation flows off by way of the earth's waters or seeps into the soil and so contributes to the formation of groundwater. Most of the water, however, evaporates again. Climate change has had an effect on this cycle.





The focus of KLIWA's research: climate changes up to the present day

Climate change is not a futuristic fantasy. Climate change started long since – for us as well. In order to form an estimate of climatic developments hitherto, first of all we examine data derived from the past. The investigation of serial readings over a number of years enables us to determine the natural range of fluctuation of weather data and so recognise trends. Under the auspices of KLIWA, data from more than 350 weather stations and 100 rivers in the south of Germany has been evaluated.



At the top of the Zugspitze, the retreat of the glacier resulting from global warming is clearly visible.

IT HAS BECOME HOTTER

The average annual temperature in the south of Germany rose by 0.8-1.3 °C in the period from 1931 to 2005. The steepest rise in the last century is found starting from the 1990s. On average the temperature increase in the winter months (November to April) is greater than in the summer months.

DREAMING OF A WHITE CHRISTMAS – CHILDHOOD MEMORIES

Milder winters mean less snow. Here too there is a clearly distinguishable trend when we look at the serial readings over the years. Above all in lower-lying areas (up to 300 meters above sea level) and in western parts of the country, the years from 1951/52 saw a reduction of snow coverage by 30 to 40 percent, with a 10 to 20 percent reduction at moderate altitudes. Only on the higher ground was there actually an increase in snowfall in some areas. Snow coverage is an important factor for the water cycle, having an effect on the replenishment of water bodies and the formation of new groundwater.wasserneubildung.

DRY SUMMERS, RAINY WINTERS

In most areas, annual precipitation rates remained more or less constant over the period under investigation. But the distribution of precipitation has altered: the winter months have become wetter, the summer months drier. In some regions precipitation has increased, in winter above all, by as much as 35 percent. Areas particularly affected in Baden-Württemberg are the Black Forest and the northeast; of the state; in

Bavaria it is Franconia and parts of the Bavarian Forest, in Rhineland-Palatinate the Eifel and Westerwald regions.

CYCLONIC WESTERLY: THE WEATHER THAT BRINGS THE RAIN

The higher precipitation rates in winter are to be put down to the increase in certain large-scale weather patterns over Central Europe. A time series analysis from 1881 to 2004 has shown that there has been a rise in what are known as zonal circulation patterns, especially in the months from December to February. One large-scale weather pattern with particular significance for the water cycle is the 'cyclonic westerly', which is driven by high pressure in the Azores coupled with low pressure over Iceland. This current of air extends from the Atlantic to western Europe, and it often brings copious precipitation. With the mild sea air, when this falls in the plains it generally takes the form of rain. But zonal weather patterns can also be responsible for violent winter storms. Sad examples are Hurricane Lothar, which blasted a trail of devastation through western Europe in December 1999, and more recently Hurricane Kyrill and Hurricane Emma in January 2007 and early March 2008, respectively.

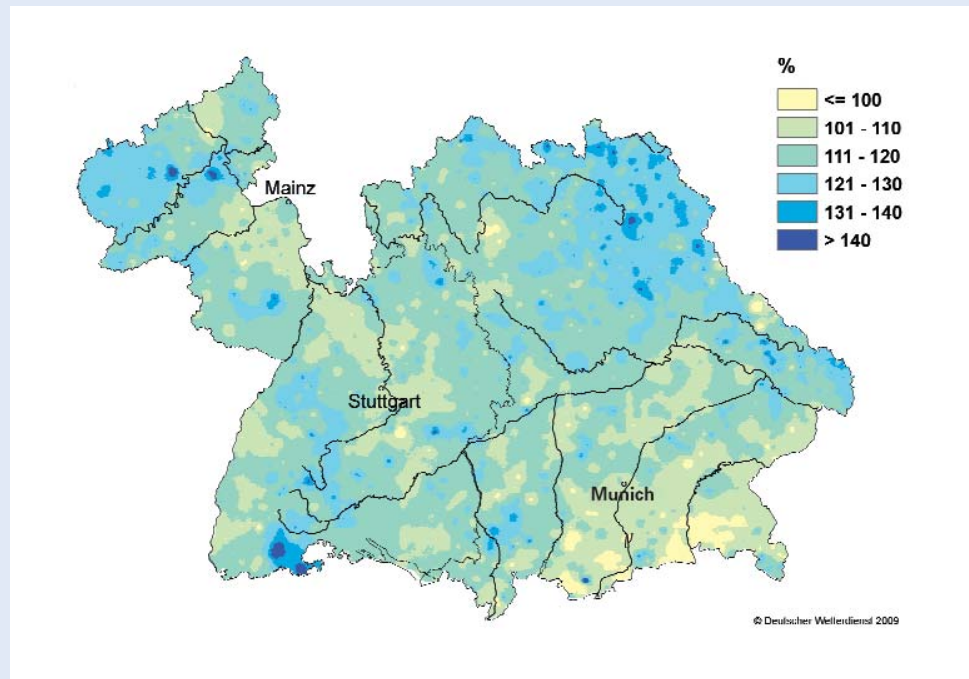
WHERE DOES ALL THE RAIN GO TO?

Readings of selected river levels taken over an extended period show that the number of flood disasters in Baden-Württemberg, Bavaria und Rhineland-Palatinate has increased over the last 30 years, above all in the winter months.



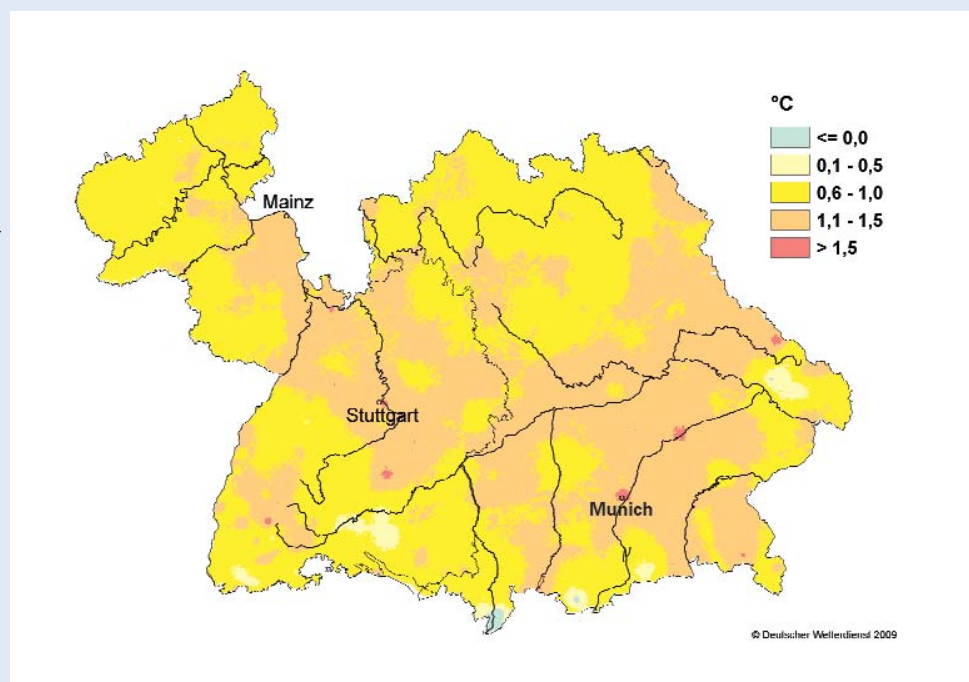
INCREASED PRECIPITATION IN WINTER

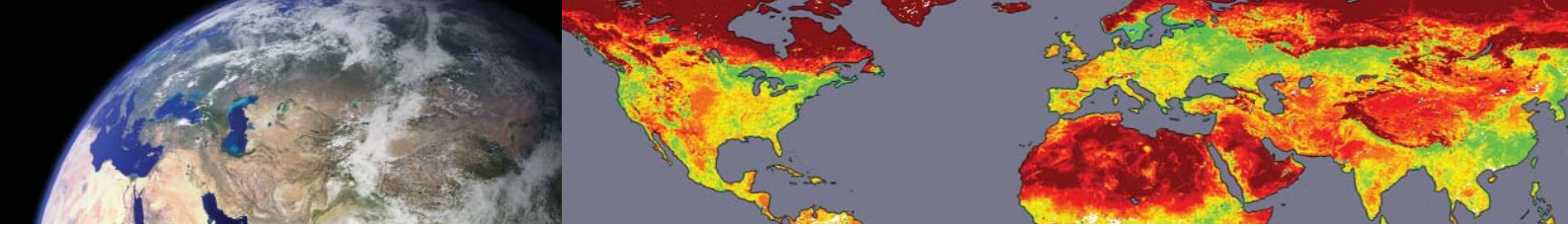
The illustration shows the relation of the average precipitation rate in the winter months (December to February) from 1978/1979 to 2007/2008 to the corresponding mean for winter precipitation in the period from 1931 to 1960.



TEMPERATURE INCREASE IN WINTER

The illustration shows the change in the average temperatures of the winter months (December to February) from 1978/1979 to 2007/2008 in comparison with winter temperatures for the period from 1931 to 1960.





Instruments of climate research: global and regional climate models

It cannot be doubted any longer that global climate change is happening, Even speedy and effective measures to protect the climate cannot prevent the climate changes that are beginning to make themselves felt, as the carbon dioxide already released into the atmosphere will continue to have an effect there for several decades and so continue to exacerbate the development. Even if emissions could be reduced to zero – a utopian prospect in view of the world's insatiable energy demands – climate change would inevitably advance further.

WEATHER – A CONSEQUENCE OF THE CLIMATE

... but there's more to it than that – the properties of the earth's surface also have an effect on the climate.

Some examples:

- Europe has a relatively mild climate considering its latitude, thanks to the Gulf Stream, a warm ocean current.
- Areas of snow and ice make the climate cooler, because they reflect the sunlight.
- Rain falling in forested areas generally evaporates again, while on sealed surfaces (as in cities) it generally disappears into gullies and drains.

GLOBAL CLIMATE MODELS

Weather forecasts are often tricky. We all know about planning a trip when a sunny day is forecast, and finding ourselves standing in pouring rain. With today's resources, a reliable weather forecast is only possible for a period of 5 to 7 days at most. Long-term predictions of the development of the earth's climate are a vastly more complex task, since so many parameters and variables that affect one another must be taken into account. This results in a practically unmanageable flood of data, and a computational complexity that can only be tackled with the help of high-performance computing resources.

Global climate models are in all cases based on an atmospheric model. This is supplemented by ocean, snow, ice and vegetation models. Anthropogenic influences (the 'human factor') are taken into account by the various IPCC scenarios. For the purposes of global climate modelling, the earth is placed on a grid. The computational capacity of today's computers currently allows for a grid width of around 150 kilometres. As a result of the variability of certain factors – estimates of world population growth, economic growth and increased energy consumption – as well as the uncertainty of the models themselves, the various results (for temperature and precipitation, for example) lie across a certain bandwidth. Hence we find forecasts that by the year 2100 the global mean temperature could rise by anything between 1.1 and 6.4 °C.

THE DEVIL IS IN THE DETAIL: REGIONAL CLIMATE MODELS

When it comes to regional climatic estimates, the grid width of a global climate model is of course insufficiently precise. Regional features like mountain ranges and river valleys would literally fall through the mesh. If we want to derive regional climate projections from global climate models with the detailed resolution that is needed, there just is no ideal procedure available to us at present.

DERIVATION OF REGIONAL CLIMATE PROJECTIONS

Basically there are several different methods available, but each of them has various weaknesses. This means that there is still a considerable need for research in this field.

- statistical methods (e.g. STAR, WETTREG)
- dynamic climate models (e.g. REMO, CLM)

For the area covered by KLIWA, different regional climate projections based on the ECHAM 4 and ECHAM 5 global models are available. From these KLIWA has selected the following projections:

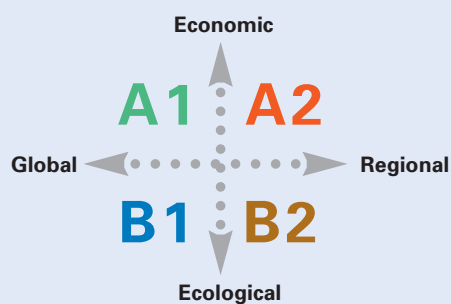
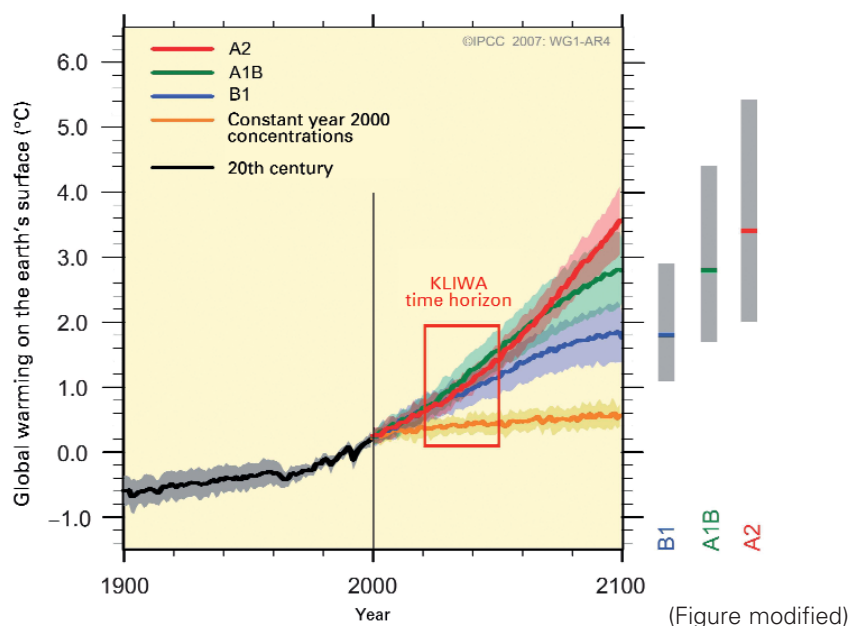
- WETTREG-2003/B2
- WETTREG-2006/A1B

A comparison of climate variables for the periods 1971-2000 and 2021-2050 yields insights about the scale of climate change.

GLOBAL WARMING ON THE EARTH'S SURFACE

Modelling results based on emission scenarios developed by the International Panel for Climate Change (IPCC) show the possible consequences of global warming for our planet.

For purposes of regional simulation, the less restrained emission scenario A1B (green line) has been adopted as defining the possible climatic future. Scenario A1B falls within the A1 family of scenarios. Along with technological developments in the energy sector, the main emphasis of this scenario is on the future balanced use of fossil and non-fossil combustible fuels.



- A1** A world with rapid economic growth and the rapid introduction of new and efficient technologies
- A2** A heterogeneous world with an emphasis on traditional values
- B1** A world turning its back on materialism, backed up by the introduction of clean technology
- B2** A world focusing on local solutions for economic and ecological sustainability.



Water budgeting models: runoff simulation tools

So if we want to determine changes in the hydrological components of the water cycle in consequence of climate change in the south of Germany (especially the accentuation of floodwater runoff or changes in low water runoff), we have to feed the results of regional climate models into water budgeting models that have a high degree of resolution.



With increasingly mild winters, there is a greater danger of flooding in the south of Germany, especially in the winter months.

RIVERINE AREAS IN GRID FORMAT

Water budgeting models serve to calculate the spatial and temporal distribution of essential components of the water cycle – such as precipitation, evaporation, seepage, water storage and runoff. They help us to display and evaluate the effects of changes on the entire system that the water cycle represents. Water budgeting models describe the following hydrological processes on a 1 x 1 km grid: evaporation, snow accumulation, compaction and melting, soil water storage, flow patterns in bodies of water and retention of water in lakes.

Possible applications of water budgeting models:

- Estimate of the effects of environmental change (e.g. possible climate changes or changes in land use) on the water cycle, with implications for runoff, seepage and evaporation
- Ongoing runoff predictions for low water, medium water levels and floodwater as a basis for operations – e.g. so as to improve low water management and flood precautions (flood predictions and early warning systems)

- Regional investigation of the water budget on the basis of river catchment areas based on the EC Framework Water Directive
- Provision of hydrological input variables for water quality and groundwater models (with implications for the heat and oxygen balance, groundwater currents and transport etc.).

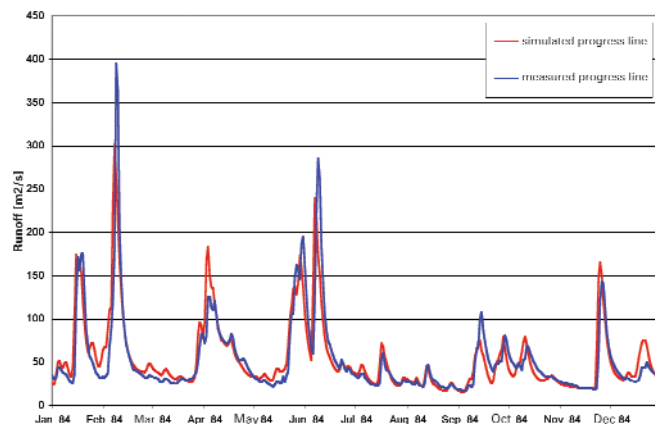
ON A FINE SCALE – THE WATER BUDGETING MODEL TOOLBOX

In order to estimate the effect of climate change on the water cycle, water budgeting models on a 1 x 1 km grid have been created for KLIWA's riverine areas. The initial aim of the modelling for KLIWA was to investigate the increased danger of flooding to be expected. Today the emphasis is rather on the investigation of low water patterns. For this purpose the daily runoff from KLIWA's riverine areas, present and future, is being computed. This approach is supplemented by special soil water cycle models that serve to determine the formation of new groundwater.



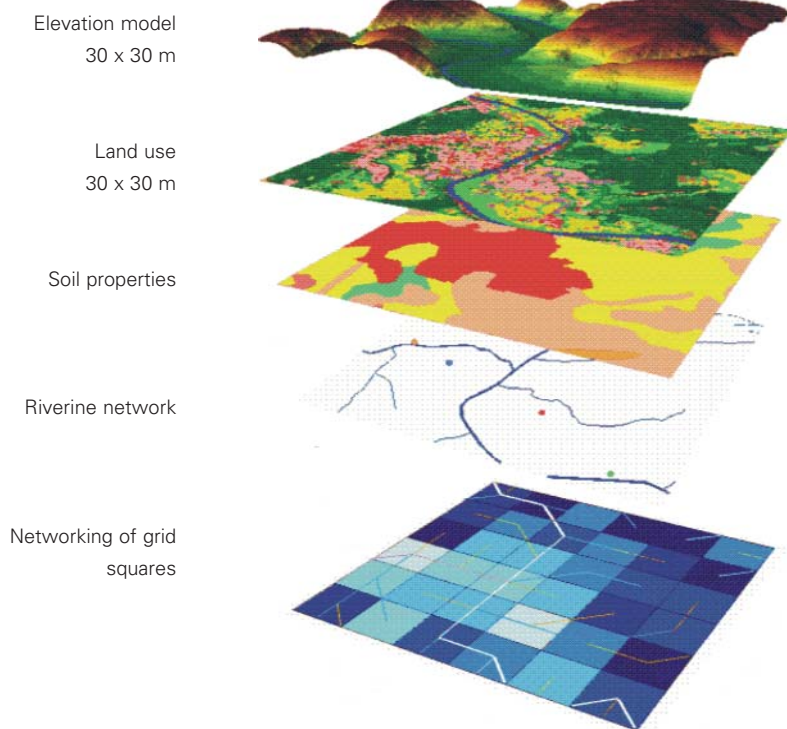
PROGRESS LINE DIAGRAM

Illustrative contrast of a measured progress line for water runoff and a simulated one based on a water budgeting model, with a level for the year 1984.



DATA BASIS FOR WATER BUDGETING MODELS

The basis for the creation of water budgeting models (WBM) consists in extensive digital data records (e.g. digital elevation models, satellite classification of land use, soil properties and riverine networks). For each separate WBM grid square up to 16 different land use scenarios are computed, each with its specific evaporation and runoff characteristics.





Future simulations, 2021 to 2050: **tomorrow's climate**

Various different climatic models may be used to simulate future conditions. The climate projections applied result in a broad range of values, for both temperature and precipitation. The results of regional climate simulation for the years 2021 to 2050 may vary in certain places, but the general tendency points in the same direction – in winter it is becoming warmer and wetter, while summers are getting drier.



As a result of climate change, apple trees will blossom up to two weeks earlier in some regions.

RATHER HOT, AND WITH LESS ICE

Climate simulations show that by 2050 mean temperatures may increase by 0.8 to 1.7 °C. In summer the mean daily temperature could rise by as much as 1.4 °C. In winter the temperature increase comes to as much as 2 °C, with the steepest increase falling in the months of December to February. This means that more rain and less snow is likely to fall, so more flooding in winter can be expected.

By comparison with today, the number of summer days (days with a temperature of 25 °C or more) will increase significantly. The number of hot days (days with a temperature of 30 °C or more) will double in almost all areas. On the other hand there will be fewer freezing days (temperature lows of 0 °C or less) and icy days (where the temperature remains below freezing point). The 'ice saints days' (cold snap in early spring) will fall later, and the last late frost will occur earlier – in some regions apple trees may blossom as much as two weeks earlier than at present.

ONGOING WESTERLY WEATHER CONDITIONS

Westerly weather conditions (especially the 'cyclonic westerlies') are responsible for high levels of precipitation today, and they will be an increasingly important factor in determining our winter weather in the future. This means an increased likelihood of floods.

MORE PRECIPITATION IN THE WINTER MONTHS

The higher the air temperature, the more rapid is the rate of evaporation. This in turn has a crucial effect on precipitation patterns.

In the simulation period the trend seen hitherto, with wetter winters and drier summers, will be continued. While in comparison with today there may be up to 10 percent less rain in summer, in winter there will be a considerable increase in precipitation – in some regions up to 35 percent. The highest precipitation will occur on the orographic barriers to the west of the regions under investigation.

In addition, winter days with heavy precipitation (25 mm or more) will increase sharply; in some regions the number of such days will be doubled. On the other hand there will also be more days without any rainfall, and periods of summer drought will persist for longer.

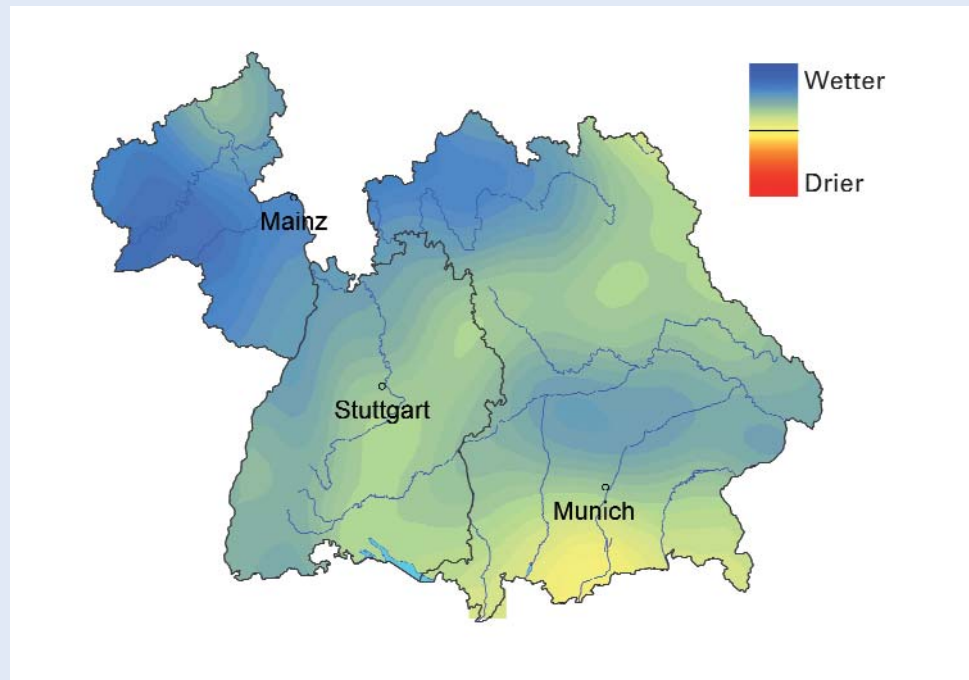
TO SUM UP: THE TREND IS SET TO CONTINUE

- It is becoming warmer, especially in winter.
- Summers are becoming rather drier, winters a good deal wetter.
- Westerly weather conditions will increase, with a tendency to higher levels of precipitation. This indicates an increased risk of flooding in the winter months.



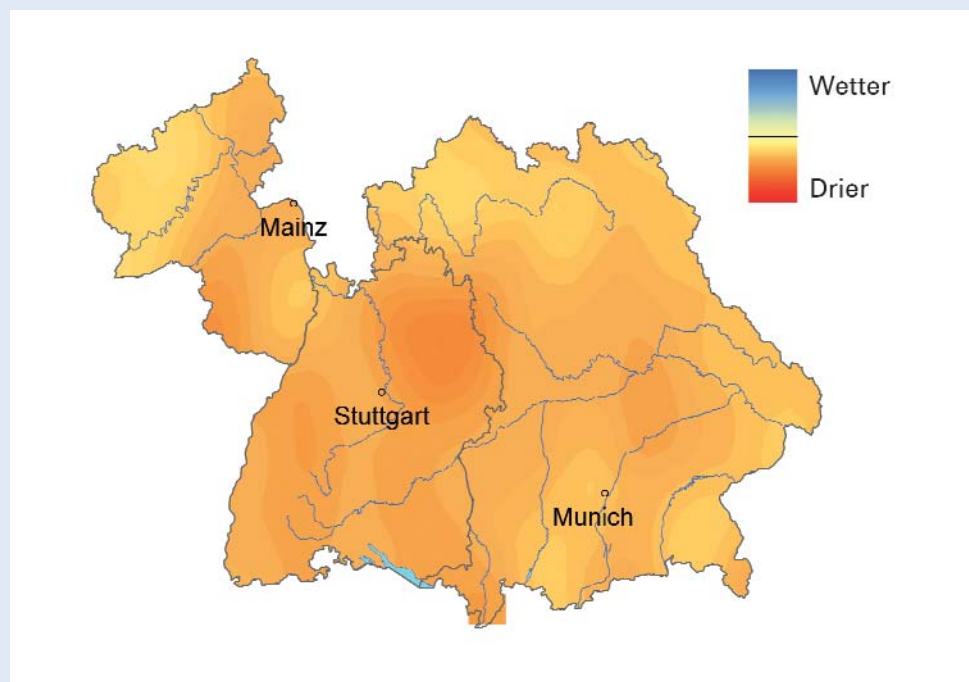
INCREASED PRECIPITATION IN WINTER

The diagram shows future precipitation changes in the winter months (2021-2050 projection, WETTREG-2006/A1B) in comparison with current levels based on 1971-2000 values.



LESS PRECIPITATION IN SUMMER

The diagram shows future precipitation changes in the summer months (2021-2050 projection, WETTREG-2006/A1B) in comparison with current levels based on 1971-2000 values.





Our most important drinking water resource: how will the groundwater be affected?

In the south of Germany something like 80 percent of our drinking water comes from subterranean groundwater reserves. So from the point of view of the water industry, the effects of climate change on groundwater resources are a very important matter. Despite changing climatic conditions we must ensure that we have a continuing supply of drinking water in future years.



Springs are bubbling, and groundwater reserves are still being generously replenished.

ONLY SLIGHT CHANGE HITHERTO

Groundwater levels and the output from springs have been under observation for several decades already – in some cases, readings go back for more than a century. Serial data obtained at special observation points yields information about the long-term development of groundwater reserves and spring output. A systematic evaluation of selected series of readings for the most important groundwater aquifers in Baden-Württemberg, Bavaria and Rhineland-Palatinate has shown that in numerous cases significant change in annual patterns has already taken place. For example, the maximum value for the year now frequently falls earlier than when readings started to be taken – this in consequence of changes in annual temperature patterns and precipitation levels. Over and above this, current statistics do not as yet support any universally applicable conclusions about a 'climate signal' in relation to groundwater levels.

PROBABLE DEVELOPMENTS FOR THE FORMATION OF NEW GROUNDWATER

Based on mean levels of today, the new groundwater that is formed in Baden-Württemberg and Bavaria comes to somewhat more than 200 mm; in Rhineland-Palatinate it is somewhat more than 100 mm. Compare this with precipitation levels – around 960 mm in Baden-Württemberg, in Bavaria around 920 mm and some 760 mm in Rhineland-Palatinate. Projections for the period from 2021 to 2050 anticipate only slight deviations in relation to the annual average formation of new groundwater. Soil water cycle computations based on climate scenario WETTREG-2006/A1B result in a slight

(4 mm) increase in groundwater formation for Rhineland-Palatinate, with a decreasing tendency (9 to 13 mm) in Baden-Württemberg and Bavaria. The sharpest decline is to be expected in southern regions; the biggest increase, on the other hand, will be in the northwest of the region considered by KLIWA. Changes in the distribution of precipitation – with less rain in summer and higher precipitation in the winter months – will have effects on seepage water levels. In summer there will be less seepage water, in winter there will be more than in the past.

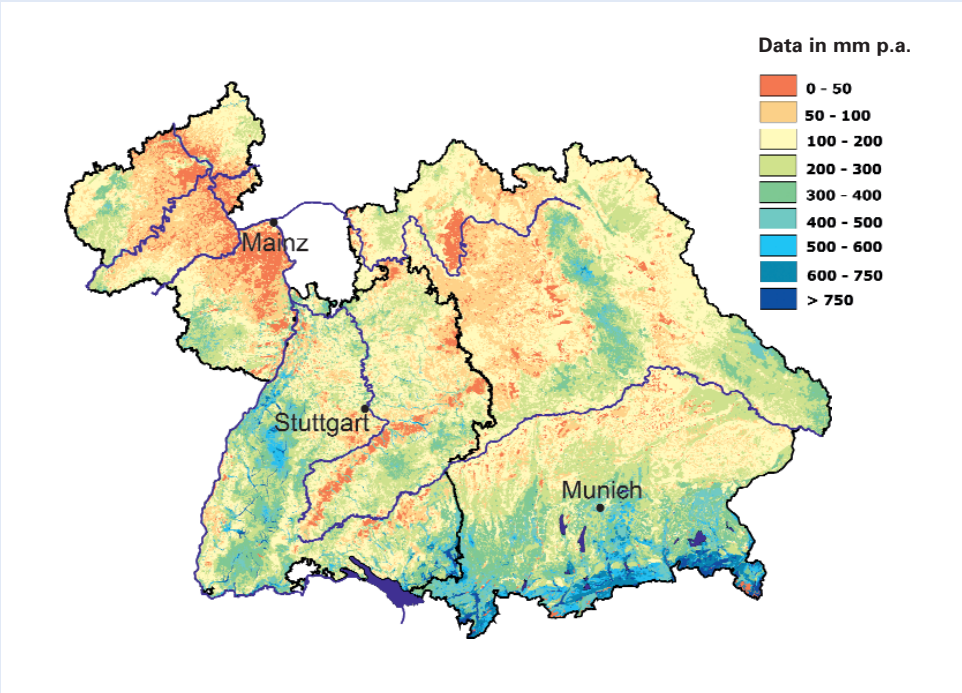
WHAT NEEDS TO BE DONE?

The basis for sustainable groundwater management is the regular observation of groundwater quantity and quality. With this end in mind, groundwater observation networks have been operating in all three federal states for a good many years. Above all in view of the possible impact of climate change, it is essential that this observation network should be consistently maintained. Even today, extended droughts in summer can already result in spatially and temporally restricted difficulties with the water supply. In order to counter these supply difficulties adequately, a number of measures are required. These include the continuing development of regional and supraregional networking solutions, and more effective methods for the sprinkler-based irrigation of agricultural areas that need it. Besides extended periods of drought in summer, we can also expect to see longer periods with heavy precipitation in future, in winter above all. This can lead to high groundwater levels locally. This should be taken into account in the planning of development areas, particularly when water saturation represents a potential hazard.



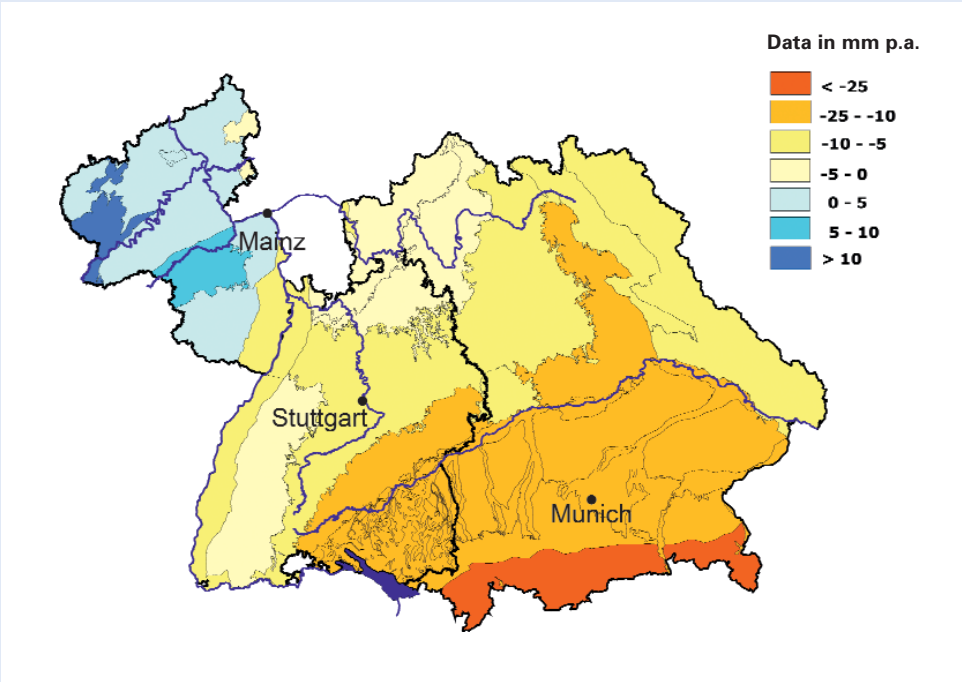
MEAN AVERAGE ANNUAL FORMATION OF NEW GROUNDWATER FROM PRECIPITATION TODAY (1971-2000 DATA)

Under the auspices of KLIWA, the formation of new groundwater in the period 1971 to 2000 has been consistently calculated right across the board for all three federal states.



CHANGE IN THE FORMATION OF NEW GROUNDWATER FROM PRECIPITATION IN FUTURE (2021 TO 2050) IN COMPARISON WITH TODAY'S (1971-2000) LEVELS

Based on this, the effects of climate change on the soil water cycle and formation of new groundwater for the future period from 2021 to 2050 have been investigated, using the WETTREG-2006/A1B regional climate projections.





More frequent and longer lasting drought: low water is becoming more prevalent

The drier and hotter summers to be expected in future will mean lower water levels. This means difficulties for inland waterway shipping – but there is more to it than that: periods of drought also represent a challenge for agriculture and the energy industry. Extreme low water is a serious economic problem. The damage to the German economy resulting from the persistent drought of 2003 was worse than that caused by one of the recent flooding catastrophes on the Rhine, Oder or Elbe. Drought above all affects many extensive areas of land, with implications not just for the water cycle but also for the flora and fauna. And the effects are more persistent than those of a flood.



Long periods of drought desiccate the soil and mean loss of harvests.

FALLING WATER LEVELS IN SPITE OF EXTREME WEATHER CONDITIONS

Higher temperatures lead to more rain in winter but less in summer. The water industry will have to adapt to the resulting changes in precipitation patterns. Extreme weather conditions will occur more frequently, with periods of drought on the one hand (like the hot summer of 2003, when streams and small rivers dried up, inland waterway shipping came to a stop and groundwater levels dropped severely) and floods caused by persistent heavy rain on the other. Recent examples of the latter were the flooding on the Upper Rhine in August 2007, and the June 2008 flood catastrophe in the Schwäbische Alb region, when the Starzel, an inconspicuous stream in the past, rose within minutes to become a torrent that caused severe damage in several districts.

LESS RAIN + MORE EVAPORATION = LOWER WATER LEVELS IN SUMMER

Climate models predict a further decrease in summer precipitation levels in future. At the same time, evaporation will increase as a result of the higher air temperature. The likelihood of serious drought occurring has increased sixfold since 1985.

Scenarios resulting from climatic modelling show a strong to serious decrease in mean monthly low water discharge from June to November in the riverine areas of Baden-Württemberg and Bavaria under investigation. The sharpest decline is likely to be found in the autumn months from

September to November. With 21 percent less low water discharge in the month of September, the decline is most marked in the southeast and southwest of Baden-Württemberg. Only in the catchment area of the Nahe in Rhineland-Palatinate do we find an increase, ranging from slight to significant (see diagram, top right). The annual progress of the changes is shown in the diagram at the bottom right.

In most regions low water periods will be longer lasting. South of a line drawn between Karlsruhe and Coburg we find a difference of up to 50 percent; to the north of this line (including the Nahe catchment area) it is a 25 to 50 percent difference.

WORST CASE NOT COVERED

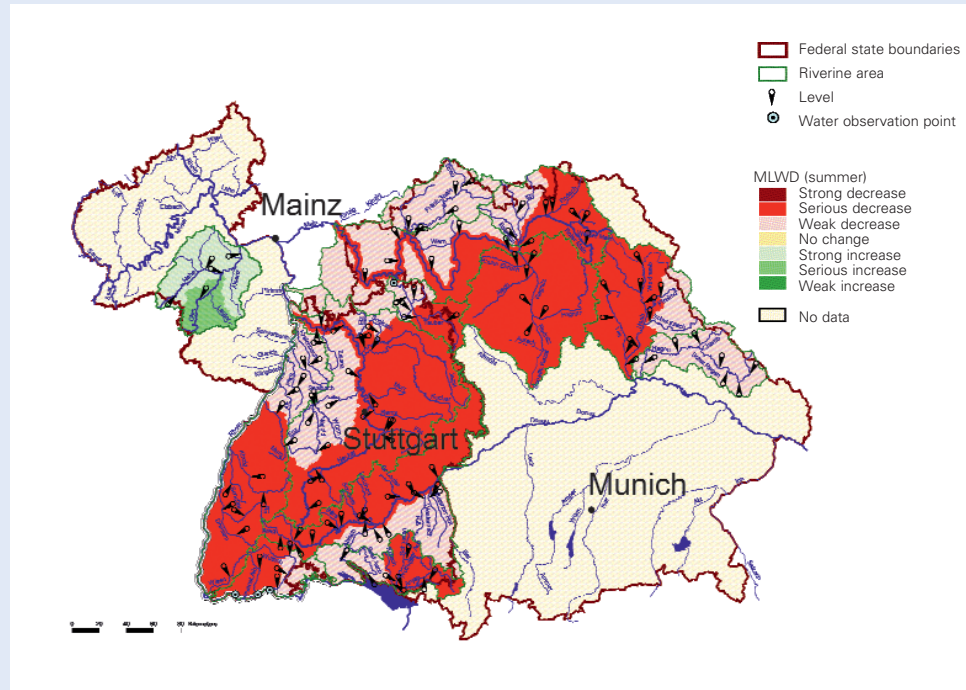
The runoff projections under consideration show that low water conditions are heavily influenced by the mean air temperature. The computations assume a rise in mean annual temperatures of around 1.0 °C up to the year 2050. But as the projections vary considerably, based on the climate model and the scenario, with a range of difference between 1.0 and 1.8 °C, low water discharge and periods of low water could actually turn out very much worse than predicted.

A future task for KLIWA will thus be to work towards the development of still more accurate regional climate models, to test these and work out adaptation strategies. The Rhine and the rivers of the Bavarian Alps will be the principal focus of future studies.



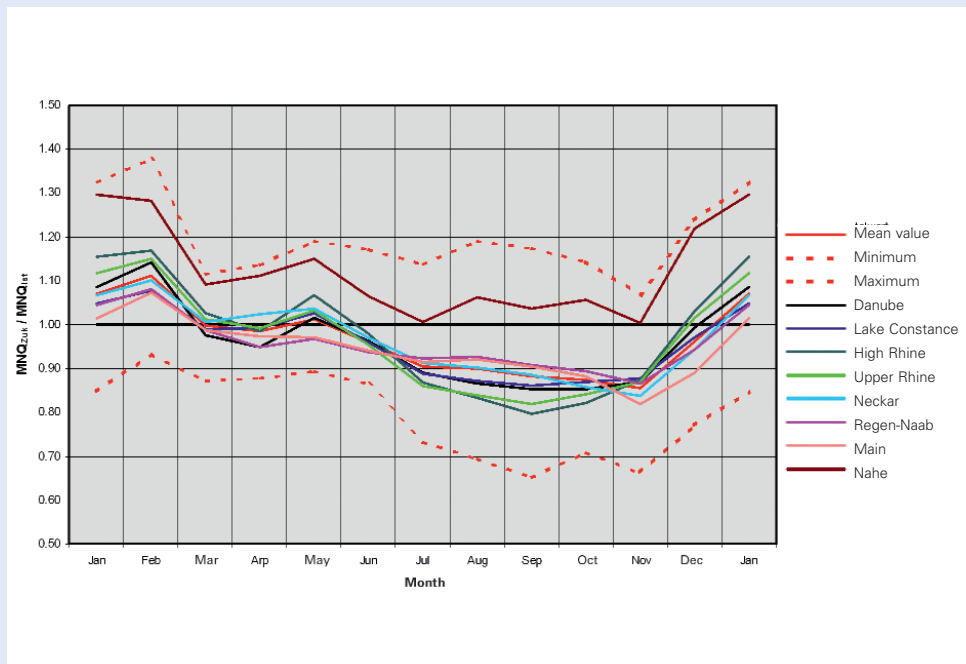
LOW WATER DISCHARGE IN FUTURE

Geographical distribution of the expected changes in mean low water discharge (MLWD) for the months June to November, derived from the monthly low water discharge levels for the riverine areas under investigation



ANNUAL PATTERNS OF LOW WATER DISCHARGE

The diagram shows changes in the patterns of average monthly low water discharge over the year, as a relation of future to current low water discharge for the riverine areas under investigation represented in the diagram above. Lines less than 1.0 indicate future decrease, over 1.0 future increase of low water discharge levels.





A strategy of flexibility and no regrets: flood protection

Even if the chain leading from the global model to the regional model and thence to the water budgeting model is subject to uncertainty, the findings nonetheless indicate that we can expect to see more flood catastrophes in future. So a flood response strategy has been developed as a precautionary measure. Response, in this connection, does not mean the universal construction of new metre-high river embankments. It is rather a matter of developing measures to meet the expected consequences of climate change – measures that will be effective in the long term and can be adapted at relatively low cost. Here flood precautions have a particularly important part to play.



FLOOD PROTECTION – WHAT DOES IT MEAN IN PRACTICE?

Example 1: flood embankment

The embankment is built as originally planned, but a sector outside it is left clear – so that in case of need it can easily be broadened and raised.

Example 2: bridge

In planning a bridge the regional climate change factor will already be taken into account, as subsequent adaptation is often impossible for technical reasons.

Example 3: retaining wall

The statics of a new retaining wall have been designed in such a way that there will be no difficulty if additional height is needed in future.

THE CLIMATE CHANGE FACTOR

The planning of flood protection facilities is generally based on the HQ100 value. HQ100 is the flood discharge which statistically speaking will be exceeded just once in 100 years. So embankments based on this value should be able to cope with a 'flood of the century'. Simulations based on water budgeting models for the riverine areas of Baden-Württemberg and Bavaria show that high water discharge levels are likely to increase almost universally, especially in winter. So both federal states have decided that in planning new flood protection facilities the effects of climate change shall be taken into account by the inclusion of a climate change factor.

On the Neckar, for example, it was found that the discharge for a flood of the century (HQ100) will rise by 15 percent between now and 2050. So from now on the HQ100 value must be multiplied by a climate change factor of 1.15 percent – that is to say, flood protection systems must in future be designed to cope with a 15 percent higher discharge than today's values indicate, or at least planned in such a way that they can be adapted to meet heightened requirements.

DIFFERENT CLIMATIC CONSEQUENCES AND CLIMATE CHANGE FACTORS

In Baden-Württemberg all riverine areas have now been minutely investigated. Regional climate change differences have consequences in terms of the flood discharge to be expected. Thus, for example, a climate change factor of 1.25 has been determined for the

Upper Danube area. Smaller floods, and floods of moderate severity, can also be expected to increase. The HQ5 discharge for the Upper Danube – representing a flood that can be expected to occur every 5 years – has gone up by 67 percent. So in future planning the HQ5 value for the Upper Danube must be multiplied by a climate change factor of 1.67 percent. In the High Rhine sector, the HQ5 climate change factor comes to 1.45. The lowest climate change factor (1.24) is found in the Upper Swabia / Lake Constance region.

Based on research findings to date, a climate change factor has been introduced in Bavaria as well – here the statistical value of HQ100 was multiplied by 15 percent right across the board. On this basis the expected effects of climate change are already being taken into account in the planning of new flood protection measures. The fundamental data underlying the climate change factor is still being subjected to refinement and further research. This may lead to regional fine tuning in future.

In the case of Rhineland-Palatinate, the scenarios used for calculation of the climate change factor in Baden-Württemberg and Bavaria are no longer available for the simulations referred to above. It is hoped that new climate projections will lead to further findings which will cast light on the need of a climate change factor for Rhineland-Palatinate as well. At present the planning of flood protection measures in the latter federal state is fundamentally based on the peripheral conditions of the individual case, with a particular focus on the threat to the population, the potential damage caused by flooding and considerations of economic viability.

CLIMATE CHANGE FACTORS

In planning the dimensions of flood protection facilities, a markup on the hundred-years value for flood discharge takes account of the possible effects of climate change. The freeboard margin serves to prevent the overflow the flood protection barrier (e.g. as a result of higher water levels caused by waves and wind).



Future prospects

In future we can look to see hotter and drier summers, and milder and wetter winters. The change in the distribution of precipitation will have corresponding effects on the regional water cycle and so on the water budgeting of our riverine areas.

To begin with, KLIWA focussed on the problems presented by flood hazards, and worked out concrete measures for dealing with these. The main emphasis of investigation has now shifted to the effects of climate change on low water discharge and the formation of new groundwater. Changes to the water cycle have direct consequences for the use of our water resources – whether as directly tapped for drinking water and agricultural irrigation, for use as a coolant in power stations or as a transport lane for shipping. This is linked to the question of the effects of climate change on the quality and ecological status of our waters. This will be a principal area of interest for future research.

Another object of research interest is the expected increase in heavy short term precipitation, in the form of storms which can result in flooding at local level. This presents increasing problems for municipal drainage networks. As estimates of the consequences of climate change are based on data determined by means of climatic models, it is essential to go on refining these models so as to minimise the factor of uncertainty. This is another area where KLIWA hopes to be able to contribute.

Regional measures that seek to cushion the effects of climate change are one thing – but even more important are steps dedicated to active climate protection. The reduction of greenhouse gas emissions must be a top priority here. As the sluggish response of the climate system means that even if emissions were to come to an immediate stop (a purely fictitious scenario), temperatures would still go on rising in the immediate future, each and every one of us must do what we can – otherwise future generations will be confronted with even more serious problems.

Climate change is the biggest challenge facing humanity today – and it affects us all. ■

