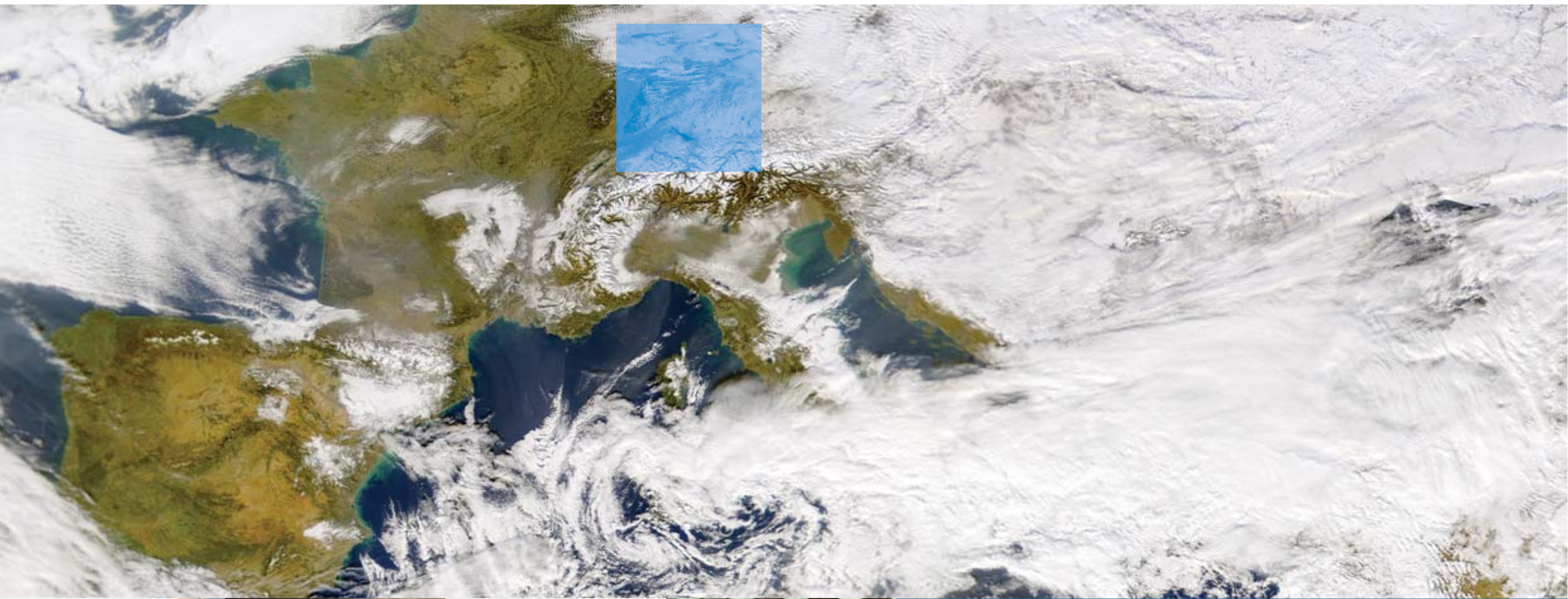
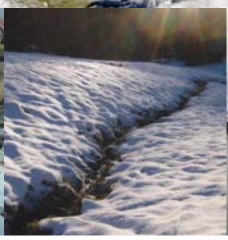
KLIWA
Climate Change and
Water Resources Management

Our climate is changing
Consequences – Extend – Strategies





IMPACT ON WATER RESOURCES
MANAGEMENT IN SOUTHERN GERMANY

DWD

Baden-Württemberg
MINISTRY OF THE ENVIRONMENT

Bavarian State Ministry for the Environment,
Health and Consumer Protection

Tanja Gönner
Environment Minister
of the German State of
Baden-Württemberg

Dr. Werner Schnappauf
Bavarian State Minister
for the Environment,
Health and Consumer Protection

Wolfgang Kusch
President of the
"Deutscher Wetterdienst"
(German Meteorological Service)

The United Nations Intergovernmental Panel on Climate Change assumes that the man-made greenhouse effect will result in a substantial increase in mean global temperature during the next few decades. This will be accompanied by a significant change in the global climate. This climate change will impact on the regional water balance. However, reliable statements in relation to the consequences of climate change at a German State or "Land" level were not possible to date. There was a lack of facts and figures in relation to how the future development of the water balance and its components was to be estimated and assessed.

The German States of Baden-Württemberg and Bavaria, together with the German Meteorological Service, have set themselves the joint aim of establishing possible effects of climate change on the water balance of the catchment areas in Southern Germany, identifying the consequences and deriving recommended action in the KLIWA Cooperation Project. Initially, an analysis and assessment of meteorological and hydrological data of the 20th century supplied the basis for estimating climate changes that had already occurred. Development of new types of regional climatic scenarios allows statements to be made on regional climatic consequences for the first time in Germany. Applying these results to the water balance models available in the German States consequently allows, in particular, statements to be made in relation to the trend in flooding phenomena during the next 50 years.

The German States of Baden-Württemberg and Bavaria have thus been the first States nationwide to introduce the climate-change factor when designing and rating technical flood defence measures. This permits the forecast increase in flood runoff to be allowed for as early as the planning stage.

With KLIWA, climate protection policy in the German States of Baden-Württemberg and Bavaria is pursuing an important module of anticipatory, foresighted provision for existential requirements.

CONTENTS PAGE

LEGAL NOTICE/CONTACT

Publisher
LUBW "Landesanstalt für Umwelt, Messungen und Naturschutz" (State Environment, Measurement and Nature Conservation Agency), Baden-Württemberg, Germany, Department 43
Hydrology and Flood Forecasting
Griesbachstr. 1
D-76185 Karlsruhe, Germany

"Bayerisches Landesamt für Umwelt" (Bavarian State Environment Agency (LfU)), Department 81, Climate Change, Climatic Consequences and Water Balance
Bürgermeister-Ulrich-Strasse 160
D-86179 Augsburg, Germany

on behalf of the Ministry of the Environment of Baden-Württemberg, the Bavarian State Ministry for the Environment, Health and Consumer Protection and the German Meteorological Service

Concept and implementation
ÖkoMedia PR, Stuttgart, Germany

As per: August 2006

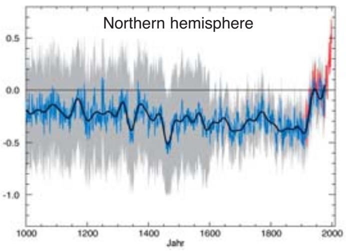
FURTHER INFORMATION

www.kliwa.de
www.um.baden-wuerttemberg.de
www.stmugv.bayern.de
www.lubw.baden-wuerttemberg.de
www.bayern.de/lfu
www.dwd.de



Is our climate going berserk...

In the year 2002, the flood of the century on the Rivers Elbe and Danube flooded whole tracts of land, and the summer of the century with temperatures soaring up to 40 °C followed in the year 2003. Worldwide, the year 2005 was the hottest year on record. In the winter of 2005/2006, snow in many areas lay so high that even snow ploughs gave up and the roofs of stadiums collapsed since they were unable to withstand the unusually heavy weight of snow. Is this string of weather catastrophes simply an extreme coincidence or does it indicate that climate change is already in full swing?



Deviation in mean annual temperature (°C) from average temperature on mean basis in the long term between 1961 and 1990. As the graph indicates, the climate has become clearly warmer in the northern hemisphere as of the start of the 20th century.

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

The earth's climate has been subject to countless major natural fluctuations over the course of the millennia. Sometimes, Europe was a tropical region and sometimes mighty ice sheets bore down on the land. Sedimentary drilling cores, pollen analyses and tree rings provide information on the earth's early climatic fluctuations. Weather data has been recorded regularly and systematically since around 1860. Evaluation of this data worldwide indicates that the average global temperature has increased by around 1 °C since climatic records have been available. This does not appear to be a major change but it is rather worrying if we consider that it was only 4 to 5 °C cooler than today during the last ice age that ended around 10,000 years ago.

GREENHOUSE EARTH

We can thank the natural atmospheric greenhouse effect for our current pleasant global average temperature of +15 °C. The earth's atmosphere that surrounds our planet like a warming jacket consists of 78 percent nitrogen, 21 percent oxygen and one percent noble gases. There are also traces of the gases hydrogen, carbon dioxide and methane, making up only 0.1 percent of the atmosphere. These trace gases act in the same way as the vast windows of a greenhouse: they allow the sun's short-wave rays to pass and they partially hold back the long-wave thermal radiation. This is why they are also referred to as greenhouse gases. Without the natural greenhouse effect, the average temperature on the earth would be around –18 °C, very hostile to life.

Historical climatic fluctuations are attributable to natural causes such as changed solar activity and the earth's rotation - and occurred over periods of time in the order of magnitude of 10,000 or 100,000 years. However, the carbon dioxide content of the atmosphere that remained relatively constant during the last century at around 280 ppm (parts per million) has been rising since the start of the industrial age. The current figure (2006) is 377 ppm, and the annual rate of rise is around 1.5 ppm. This anthropogenic (or man-made) greenhouse effect causes an increase in the earth's temperature. The greenhouse gas content of the atmosphere has a crucial impact on global temperature. Consequently, it is important to be aware of the bandwidth of future global temperature by using true-to-life assumptions of greenhouse gas concentrations in order to achieve an accurate prediction of the earth's climate.

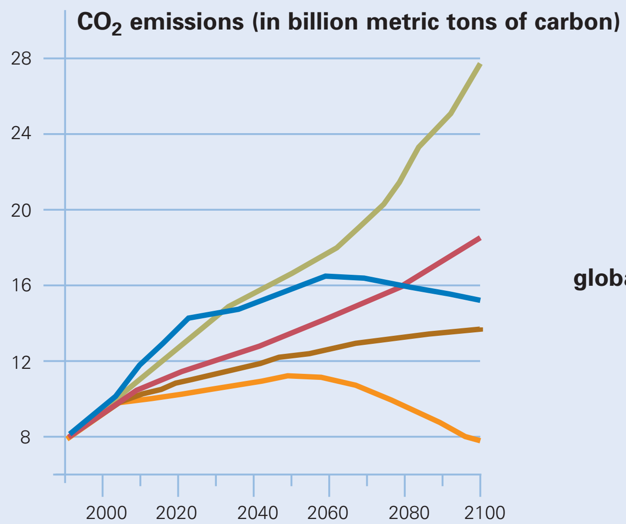
OH MAN! – WHAT ARE WE DOING TO THE CLIMATE?

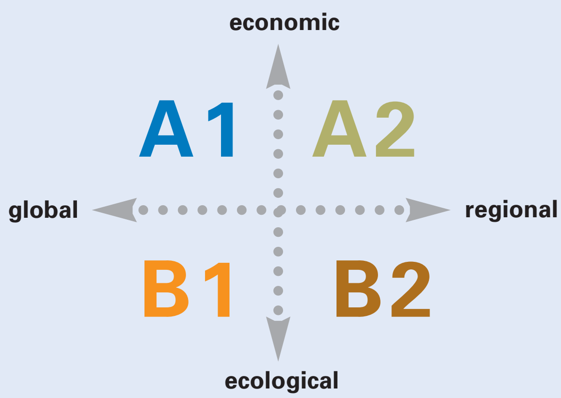
Consequently, in order to be able to realistically estimate how the earth's climate will develop, we must take into account the "human factor" besides the natural climatic factors. The United Nations Intergovernmental Panel on Climate Change (IPCC) has developed what are called emission scenarios for this. These scenarios incorporate factors such as how the world population will develop, what standard of living this population will endeavour to achieve, what fuels they will use and how much energy they will consume. The scenarios extend from a "We'll carry on regardless" society to a world population aware of the environment and turning away from materialism.

ANTHROPOGENIC GREENHOUSE GASES AND THEIR IMPORTANT EMISSION SOURCES

Carbon dioxide (CO_2)	→ Combustion of fossil fuels
Methane (CH_4)	→ Rice cultivation, cattle rearing and waste decomposition
Dinitrogen oxide (N_2O)	→ Combustion processes and traffic
Chlorofluorocarbons (CFCs)	→ Spray cans and refrigerators

IPCC EMISSION SCENARIOS





A1 A world with fast economic growth and fast introduction of new and efficient technologies.

A2 A heterogeneous world with the focus on traditional values (family values and local traditions).

B1 A world turning away from materialism, and introducing clean technologies.

B2 A world focussing on local solutions for sustained economic and ecological development.

IS92a "Business as usual" scenario (1992)


Tracking down the climate in Southern Germany with **KLIWA**

On the basis of the results of climatic modelling with various models and the IPCC scenarios, leading research institutes assume a global warming of 1.4 °C to 5.8 °C during the next hundred years. This increase in temperature will impact on the natural water cycle that may consequently lead to greater evaporation, greater cloud formation, higher precipitation and changed water flow in bodies of water.

The KLIWA Corporation Project is split into several areas, each building on the others

KLIWA PROJECT AREAS

Area A:
Determining changes in climate and water balance to date

Area B:
Estimating possible impact of climate change on the water balance

Area C:
Recording future changes in climate and water balance

Area D:
Adjusting water resources management action

In order to implement targeted regional flood defence measures, it is necessary to know what catchment areas are particularly at risk of flooding. This also necessitates a regional climate forecast. However, climate models to date were elaborated only globally or for macro-regions such as Northern Europe.

HAS CLIMATE CHANGE ALREADY BEGUN?

In view of the increased number of flood events in recent years, we must ask ourselves the question as to whether they are already harbingers of climate change or not. Are they just normal occurrences? Or will we have to live with more such extreme weather situations and floods in future? If so, can we, in this case, predict how our climate and water balance will change and how we can respond suitably to it?

THE KLIWA PROJECT

The German States of Baden-Württemberg and Bavaria and the German Meteorological Service agreed to work together in multi-disciplinary manner in the long term in the "Climate Change and Consequences for Water Resources Management" **(KLIWA)** Cooperation Project in order to research this question specifically. The aim of **KLIWA** is to establish possible effects of climate change on the water balance of catchment areas in Southern Germany, identify the consequences and draft recommended action.

INFLUENCES ON THE WATER BALANCE – PROCEDURE

The **KLIWA** Project can now boast a multitude of results. Initially, long-term meteorological and hydrological measurement data from Bavarian and Baden-Württemberg weather stations was analysed and trends were determined. These weather stations served as the basis for simulation with regional climatic models for the period 2021 - 2050. In turn, the future climatic data was used to feed finely meshed models for the water balance of the individual catchment areas. In certain cases, specific recommended action has already been voiced. Initially, the studies still focus on the flood problem. Over the future course of the study, other effects on the water balance such as low water or changed groundwater recharge are also to be examined.

BLOW ME! OUR CLIMATE

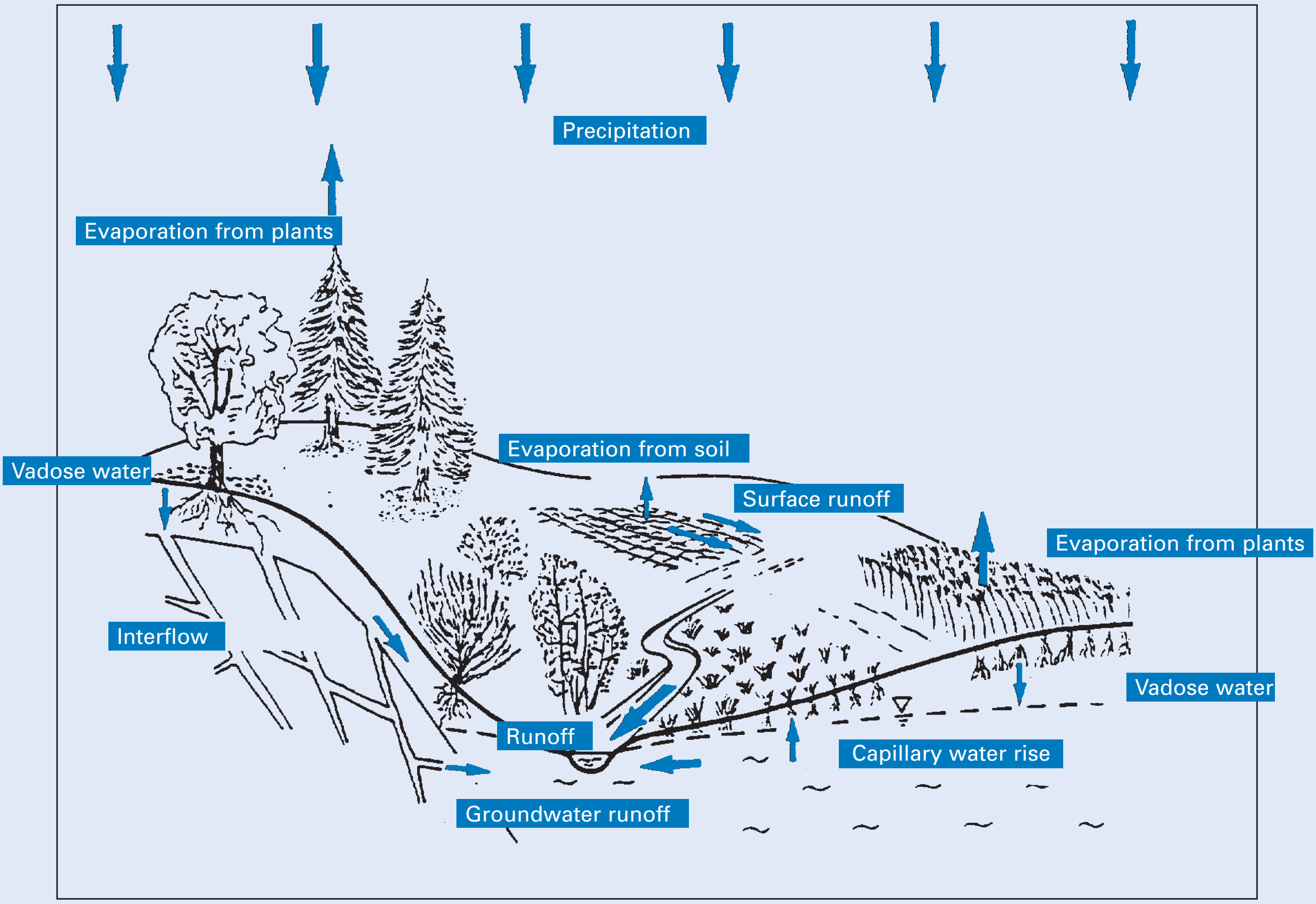
The term climate means the average, long-term behaviour of meteorological parameters, in particular, temperature and precipitation, while the term weather means the currently prevailing state of these meteorological parameters. Weather forecasts attempt to predict the time sequence of weather phenomena in the next few days as precisely as possible. By contrast, long-term climate change is mapped by climatic scenarios, i.e. describing climatic states of the future wherever possible, dependent on the future societal, economic and technical developments impacting on them. Climatic scenarios always refer to long periods in the future - at least 30 years.

KLIWA ON THE WEB

Further information on the **KLIWA** Project is available on the homepage **www.kliwa.de**. The download area provides comprehensive reports and publications, in relation to results and modes of operation, that can be downloaded.

THE NATURAL WATER CYCLE

Two thirds of the earth's surface is covered by water. This water is, by nature, not stationary but circulates around the globe in a gigantic cycle in the form of water vapour, liquid or ice. Water that evaporates from the earth's surface rises as water vapour, condenses to form clouds and falls back to the earth in the form of precipitation - rain or snow. The precipitation is discharged via bodies of water or seeps into the ground, consequently contributing towards groundwater recharge. However, most of the water evaporates again. The individual components of the natural water cycle are altered by climate change.



Schematic representation of components of the water balance (after Wohlrab et al. 1992, amended)

Focus on:
the climate in the 20th century

Climate change is not something that we do not have to think about until the future but has already long begun. In order to be able to estimate climatic trends to date, we must first investigate the data from the past. An investigation of measurements over many years allows us to determine the natural range of fluctuation in weather data and possibly identify a trend. Measured values from over 350 weather stations in Southern Germany were used for the KLIWA Project.

THINGS ARE WARMING UP

The average air temperature in Southern Germany rose by 0.5–1.2 °C in the period 1931–2000. The greatest rise occurred as of the 1990s. The mean monthly temperature increase was most pronounced in the month of December at 1.8–2.7 °C, primarily in the west and in low-lying areas up to 500 m above sea level.

WHITE CHRISTMAS – A CHILDHOOD MEMORY

Mild winters mean less snow. Here as well there is a clearly recognisable trend shown by the measurements over many years. In the years from 1951/1952, the time in which there was snow cover dropped by 30–40 percent, above all in low-lying areas up to 300 m above sea level and in western parts of the country. The corresponding figure for moderate altitudes (300–800 m above sea level), was 10–20 percent. It was only in high-altitude locations that there was even more snow than previously. Since snow is nothing other than temporarily solidified water, snow cover is an important factor impacting on the water balance, e.g. water flow in bodies of water.

DRY SUMMERS AND RAINY WINTERS

The annual precipitation has remained approximately the same in most areas during the period under investigation. However, the distribution of precipitation has changed: the winter six months have become damper and the summer six months drier.

Precipitation has increased by up to 35 percent in many regions, above all in the wintertime. The Black Forest and the north-eastern area of the German State of Baden-Württemberg and Franconia and parts of the Bavarian Forest in Bavaria have been affected by this in particular.

LOW PRESSURE FROM THE WEST: WEATHER THAT BRINGS RAIN

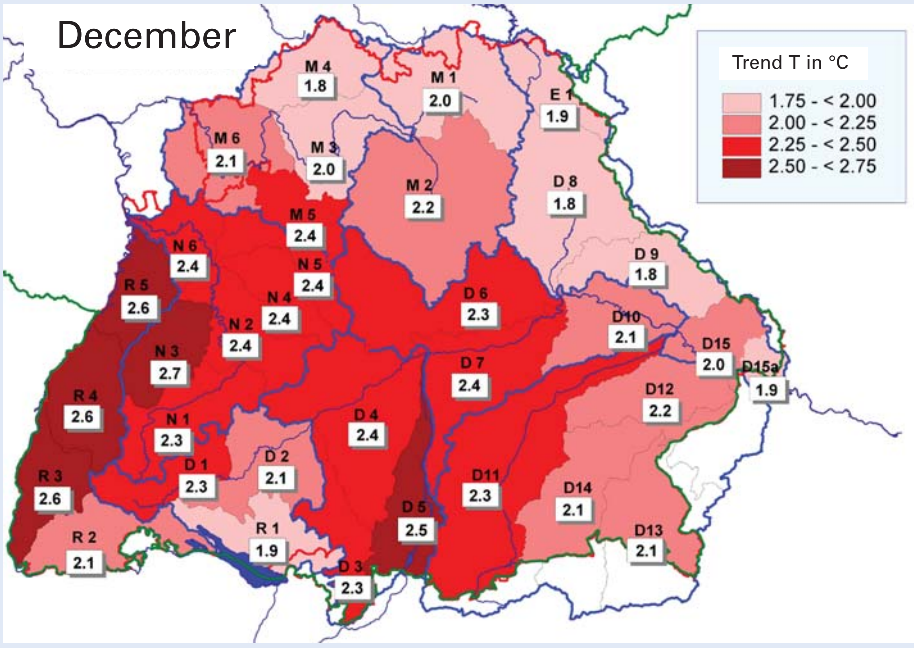
Increased precipitation in the wintertime is attributable to the increase in certain general weather situations over Europe. A time series analysis between 1881 and 1989 indicated that the so-called zonal circulations occurred more frequently, particularly in the months of December and January. The general weather situation that is most important from a hydrological point of view is the "low pressure from the west" that is driven by high pressure in the Azores and low pressure in Iceland. This air stream that extends from the Atlantic to Western Europe frequently brings with it copious precipitation - generally in the form of rain in lowland areas and on plains owing to milder maritime air. Zonal general weather situations are, however, also responsible for violent winter storms. One sad example is the storm named "Lothar" that occurred in December 1999 in Germany, that wrought a path of destruction through Western Europe.

RAIN CAUSING FLOODING

Long-term measurements at selected river level river gauges indicated that flood events in the German States of Baden-Württemberg and Bavaria have increased in the last 30 years, primarily in the winter months.

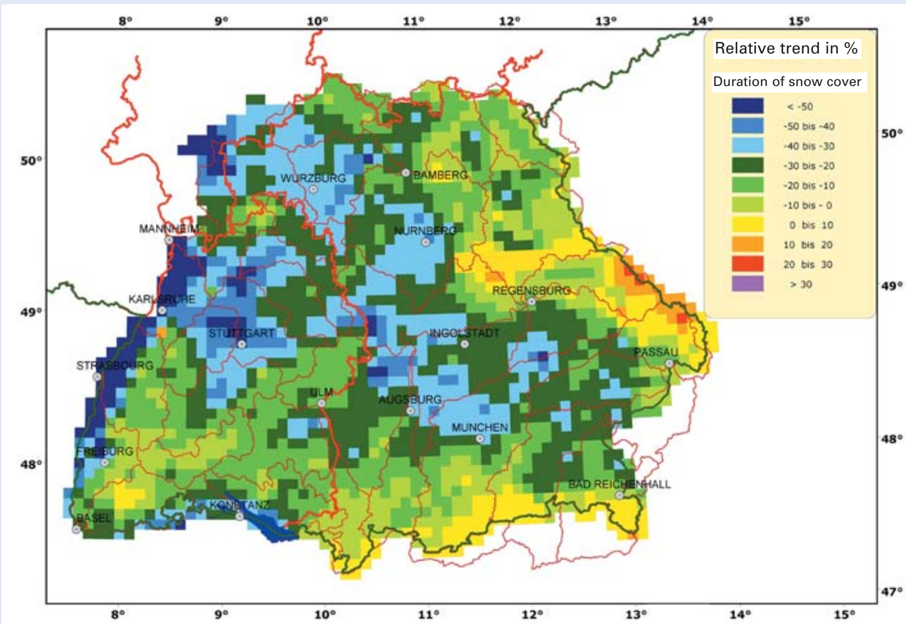
AIR TEMPERATURE

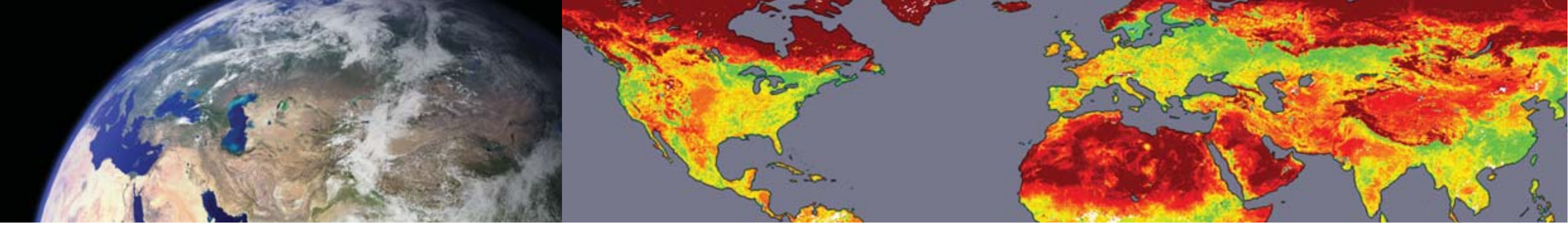
Mean temperature rise in the month of December on a long-term average between 1931 and 2000.



DURATION OF SNOW COVER

Decline in mean duration of snow cover in the period 1951/1952–1995/1996.





Climatology instruments

Almost all leading research institutes now assume that global climate change is occurring. Even fast and effective measures to protect the climate will be unable to prevent the emerging process of climate change since the carbon dioxide emitted into the atmosphere will still have an effect in 30–40 years time and will contribute to the warming process. In addition, in view of the world's current thirst for energy, it is impossible to reduce emissions to zero since more CO_2 is produced each time combustion occurs.

WEATHER - A CONSEQUENCE OF CLIMATE

... but not only a consequence of climate because the nature of the earth's surface also influences climate. Here are a few examples:

- Europe that is relatively warm in view of its latitude owes its mild climate to the Gulf Stream, a warm ocean current.
- Snow and ice sheets ensure a cooler climate since they reflect sunlight.
- Rain falling over forested areas generally evaporates again whereas rain falling on sealed areas such as in tons and cities mainly disappears down drains and flows through the sewage system into the nearest body of water.

WHAT IS THE TEMPERATURE CURVE? GLOBAL CLIMATE MODELS

Even simply predicting the weather is frequently difficult. All of us will certainly have planned an excursion only to arrive in the pouring rain while sunshine was forecast. A reliable weather forecast with today's forecasting resources can be made only for a maximum of 5 to 7 days into the future. Long-term forecasting of the earth's climate is an incomparably more complex task since many parameters and variables need to be allowed for and these parameters and variables have a mutual influence. This leads an immense torrent of data and a computing effort that can be coped with only by supercomputers.

Just like weather forecasting, global climate models are based on an atmospheric model but are supplemented by an oceanic model, a snow and ice model and a vegetation model since these factors have a substantial impact on climate. The anthropogenic influences (the "human factor") are allowed for in the various IPCC scenarios.

For the purposes of global climate modelling, the earth is split into a specific grid. The computing power of today's computers currently allows a grid spacing of around 250 x 250 km^2. Owing to the variability of the factors, a global climate model is unable to provide firm values but only a bandwidth in which, for instance, the temperature or precipitation will vary. This is why we obtain statements such as those to the effect that global temperature will rise by 1.4–5.8 °C through to 2100.

THE DEVIL IS IN THE DETAILS - REGIONAL CLIMATE MODELS

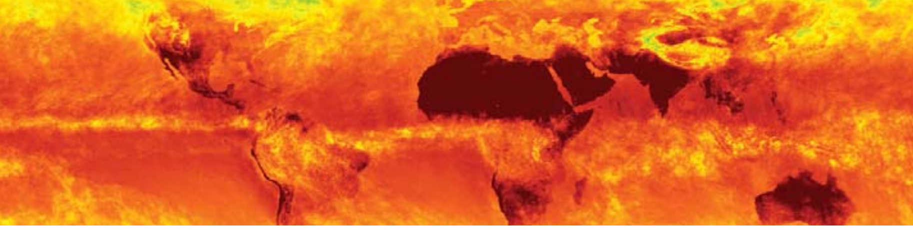
The grid mesh width of a global climate model is, of course, inadequate for a regional climate forecast. Regional topographical peculiarities such as small mountain ranges or flood plains literally fall through the net.

Since there is still currently no optimum method of elaborating regional climate scenarios from the global climate model, three different methods of simulating the regional climate were selected for KLIWA. This provides a certain bandwidth of feasible trends and comparison options.

Three methods for regional climate modelling

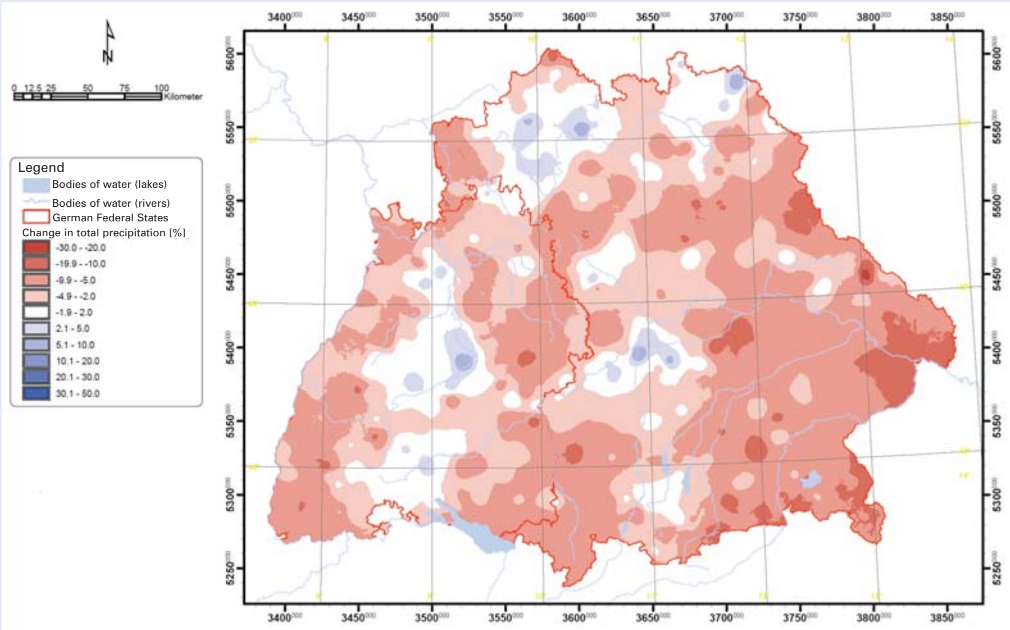
- a statistical method
- a statistical, dynamic method and
- a regional, dynamic climate model

All three methods are based on the ECHAM 4 global climate model. The "human factor" was included with the B2 emission scenario - a continually increasing world population that finds sustained local solutions to economic, social and environment problems. This simulated the period 2021 to 2050. The results obtained with the statistical, dynamic method were then used for the rest of the estimates. The changes in precipitation occurrence with this method are shown adjacently for the summer six months and the winter six months.



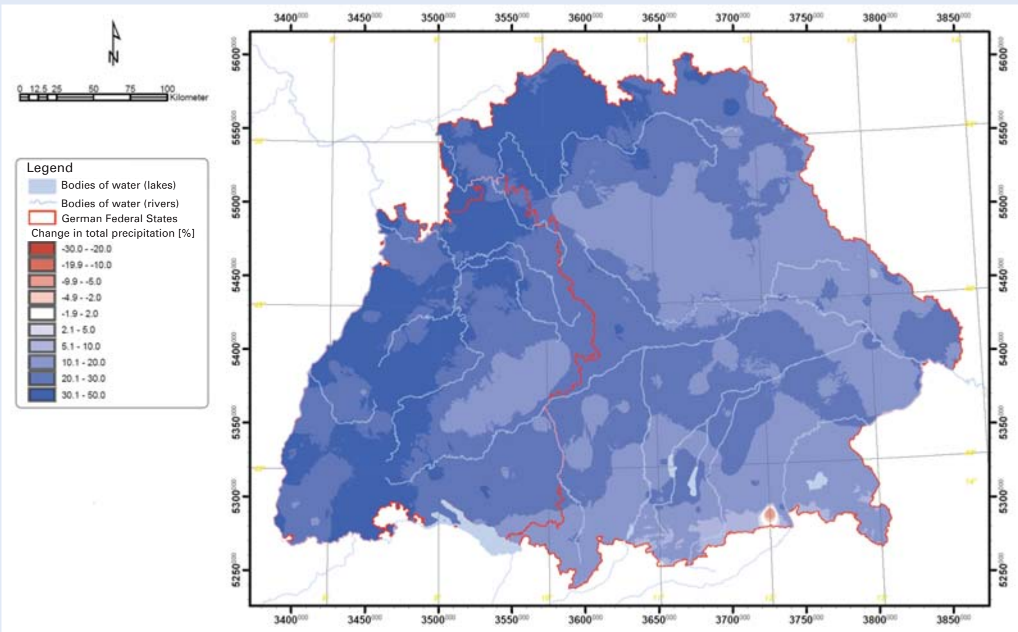
PERCENTAGE CHANGE IN MEAN TOTAL PRECIPITATION (MAY–OCTOBER) SCENARIO FUTURE VERSUS ACTUAL SITUATION

Only minor differences in the spatial distribution of the change in precipitation can be seen in the hydrological summer six months. Largely only minor reductions in precipitation occur.



PERCENTAGE CHANGE IN MEAN TOTAL PRECIPITATION (NOVEMBER–APRIL) SCENARIO FUTURE VERSUS ACTUAL SITUATION

By contrast, the annual total precipitation will clearly increase in the winter six months. This will primarily impact on the Black Forest, the "Odenwald" mountain chain, the "Spessart" hill chain and the Rhön Mountains. There will also be more precipitation along the River Danube



Water balance models
as an instrument for runoff forecasts

However, global and regional climate simulations cannot provide statements on the effects of climate change on water resources management. This is why finely meshed water balance models must be fed with the results of the regional climate models in order to determine the changes in the hydrological components of the natural water cycle, in particular the intensification in flood runoff owing to global warming in Southern Germany.

WATER BALANCE MODELS LEARN FROM THE PAST HOW TO LOOK INTO THE FUTURE

Climate scenarios for the actual situation and future scenarios were determined on the basis of the meteorological and hydrological measured data from the years 1951 to 2000 with all three methods. The quality of the simulations was checked with the measured data of 1971 to 2000, i.e. the simulation of the actual situation was compared with the actual weather data. This allowed systematic errors of the global climate model to be compensated for to a certain extent. The future scenarios obtained in this way covered the period 2021 to 2050.

In order to be able to supply precise regional data, the German States of Baden-Württemberg and Bavaria were spilt into 33 investigation areas - primarily on the basis of topographical and water resources management aspects. These areas were, in turn, combined into nine regions.

In order to estimate the impact of climate change on the water balance, high-resolution water balance models (WBMs) were elaborated on the basis of a 1 x 1 km^2 grid for large parts of the KLIWA area. For Baden-Württemberg, these models are available on a full-coverage basis. To date, water balance models have been adapted for the catchment areas to the north of the River Danube, in particular the River Main area. Initially, this focussed on investigating the intensification in flood phenomena.

For this purpose, the results of the regional climate scenarios were used as input data. A water balance model allows all components of the water balance to be calculated.

Components of the water balance

- Precipitation
- Water flow
- Evaporation
- Ground moisture
- Groundwater recharge
- Snow cover water equivalent

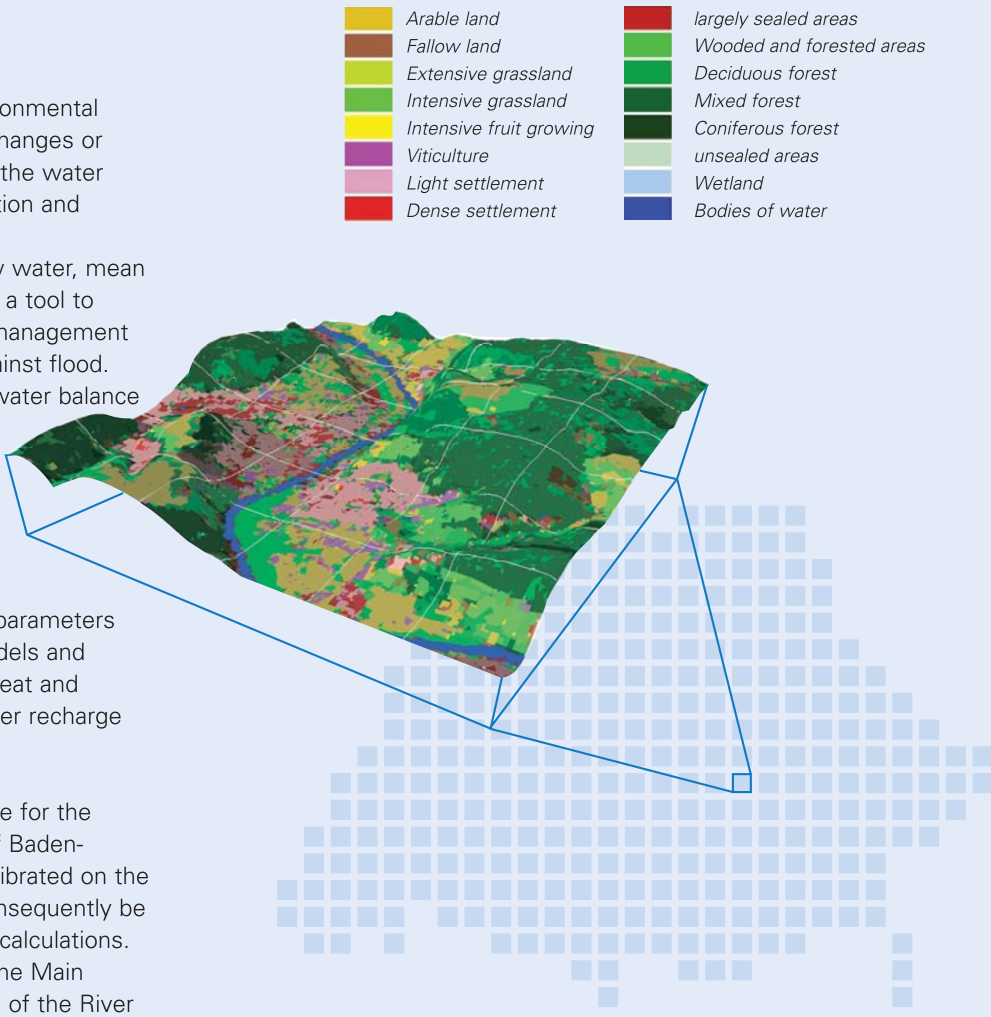
1-SQ. KM GRID

Water balance models are mathematical computing methods to describe and quantify the spatial ad time distribution of essential components of the water balance such as precipitation, evaporation, infiltration, water storage and runoff. They help us to represent and assess the effects of changes in the input components on the overall "water balance" system. The following hydrological sub-processes, among others, are described in the water balance models with a grid-based area resolution of 1 x 1 sq. km: Leaf wetting, evaporation, snow accumulation, snow compaction and snow melt, groundwater storage, surface storage and transport, flow movement in channels and retention in lakes. Neither must we forget the methods for compensating for and converting meteorological measured variables.

Possible applications of water balance models

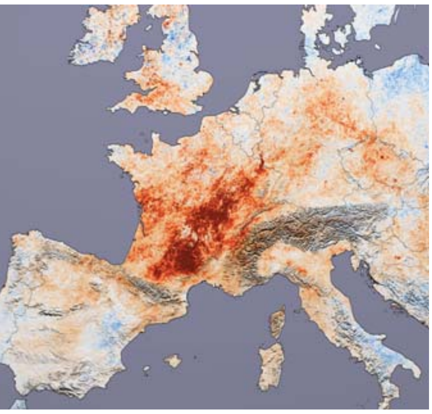
- Estimate of the impact of environmental change, e.g. possible climate changes or changes in land occupancy, on the water balance (such as runoff, infiltration and evaporation).
- Ongoing runoff forecast for low water, mean water and flood in operation as a tool to improve low water resources management and to improve precautions against flood.
- Regional investigations of the water balance on the basis of river catchment areas as defined by the EU Water Framework Directive.
- Forecasts and scenarios for water resources development planning.
- Provision of hydrological input parameters for water resources quality models and groundwater models (e.g. for heat and oxygen balance and groundwater recharge etc.).

Water balance models are available for the entire area in the German State of Baden-Württemberg. They have been calibrated on the basis of diurnal values and can consequently be used for forecasting and scenario calculations. To date, models are available for the Main region and the northern tributaries of the River Danube in the German State of Bavaria.



Tomorrow's climate – future scenarios 2021–2050

The results of the three methods for regional climate modelling do, admittedly, differ in a number of places but the trend is the same. The figures determined were compared, checked for plausibility and summarised to form regional climate scenarios.



Extreme summer of 2003: Heat wave (areas marked in red) in Europe

HOTTER AND LESS ICE

The climate situations indicate that the temperature will increase by 1.7 °C on average through to 2050. In summer, the mean daytime temperature will rise by 1.4 °C and will be 15 °C. In the wintertime, the temperature increase is higher (from 2 °C to 4.5 °C). The temperature will rise most greatly in the months of December to February. In this context, it is worthy of mention that this will cause more rain and less snow to fall. Consequently, minor and moderate floods may occur to a greater extent in the wintertime.

The number of summer days (days over 25°C) will increase greatly at all climate locations by comparison with the present day. The number of hot days (over 30 °C) will double virtually everywhere. By contrast, there will be less days following nights of subzero temperature (lowest temperature below 0 °C) and less days of subzero temperature (continuous frost). The latter will generally halve. What is referred to as the "Ice Saints" in German folklore (the name given to St. Mamertus, St. Pancras and St. Serbatus - frequently considered to be the beginning of colder weather in the northern hemisphere) will move forward: the last "late frost" will come earlier, and tomatoes will be able to be planted up to two weeks earlier in many regions.

MORE PRECIPITATION IN THE WINTER MONTHS

The higher the air temperature, the greater the evaporation of water. This, in turn, impacts substantially on precipitation behaviour.
During the simulation period, the established trend with damper winters and drier summers will continue.

However, while it will rain up to 10 percent less in the summertime by comparison with the present day, there will be far more precipitation in the wintertime - in many regions up to 35 percent more. Most of this precipitation will fall in the regions under investigation in the west. The absolute front-runner as far as precipitation goes will be the Black Forest.
In addition, days with heavy precipitation (over 25 mm) will increase substantially in the wintertime, and the number of such days will double at many measurement stations. By contrast, there will be more days on which there is absolutely no precipitation: periods of drought in the summertime will be longer.

CONTINUED WESTERLY WEATHER CONDITIONS

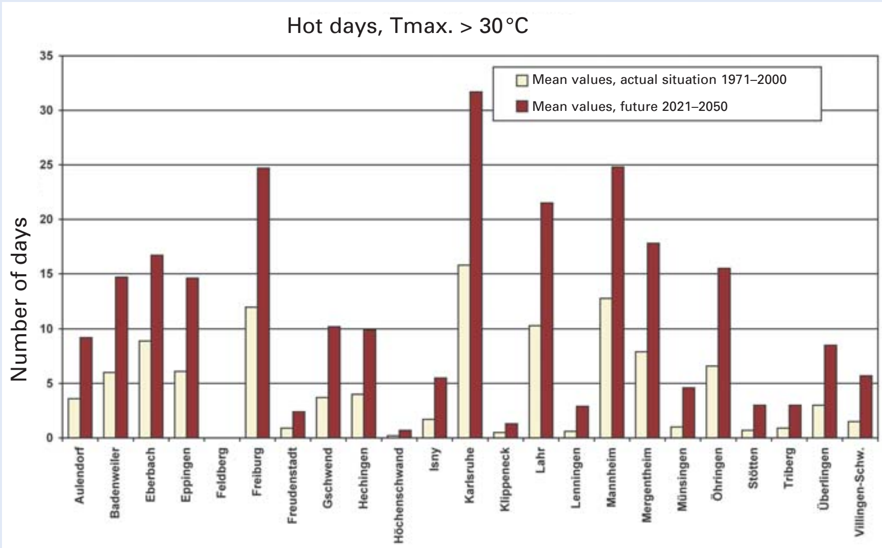
The westerly weather conditions that bring substantial precipitation, in particular the cyclonal westerly situation (WZ), will determine our weather in the winter six months more frequently in future as well. This will increase the probability of flood incidents.

UPSHOT: THE TREND WILL CONTINUE

- It will become warmer, primarily in the wintertime.
- Summers will be somewhat drier but, by contrast, winters will be substantially damper.
- The westerly weather situations that can bring higher precipitation will increase. From this, it can be seen that risk of flooding will increase in the winter six months. Moderate floods above all will increase since the snow cover may build up and thaw several times in future milder winters.

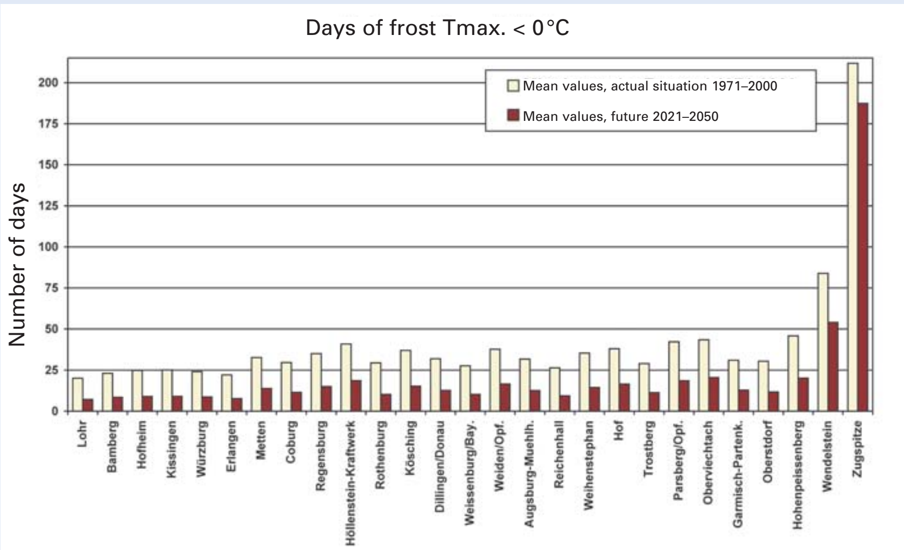
TUSCANY IN GERMANY'S BADEN REGION? HERE IS AN EXAMPLE FOR KARLSRUHE

The mean average temperature that was around 15.1 °C in the period 1971–2000 will be 17.4 °C in the future scenario. Instead of 16 hot days, there will be 32. This means that, in view of an increase in air temperature of around 2.3 °C, the probability of the occurrence of temperatures over 30 °C will double. By contrast, there will only be four days with continual frost instead of the previous eleven.



BAVARIAN WINTERS

Even in the mountains, there will be less of a freeze - the "Zugspitze", Germany's highest mountain, will have less than 180 days of frost. The figure was just under 210 per year to date.



Protection with the
"flexible and no regret" strategy

Even if the model chain of global models - regional models - water balance models is still characterised by some uncertainties, the results indicate that flood events can be anticipated to a greater extent in future. Consequently, a flood adjustment strategy has been developed in order to be on the safe side. Adjustment does not mean that metre-high embankments will now be constructed everywhere on new buildings. Rather, the aim is to stave off the consequences of the anticipated climate change by measures that are appropriate in the long term and that can be adapted at relatively low cost.

ALLOWING FOR CLIMATE CHANGE: THE CLIMATE-CHANGE FACTOR

Value HQ_{100} is frequently taken as a basis when planning flood defence installations. HQ_{100} is the flood runoff that, viewed statistically, occurs once every 100 years. The structures designed on the basis of this value are consequently intended to avert a "flood of the century". Simulations of the water balance models for the catchment areas in Baden-Württemberg and Bavaria indicate that the flood runoff figures will increase at virtually all gauging stations, particularly in the wintertime. Consequently the effects of climate change have been allowed for by a climate-change factor when designing new water resources management flood defence systems in both German States, Baden-Württemberg and Bavaria.

For the River Neckar for instance, it has been determined that water flow will increase for a flood of the century (HQ_{100}) by 15 percent through to 2050.
Consequently, from now on, the value HQ_{100} is to be multiplied by the climate factor 1.15, i.e. the installations will be rated for a 15 percent higher runoff or planned in such a manner that they can be upgraded if necessary.

New HQ_{100} value for the River Neckar:
HQ_{100} (new) =1,15 x HQ_{100}(old)

VARIOUS CLIMATIC CONSEQUENCES AND CLIMATE FACTORS

By now, all catchment areas in the State of Baden-Württemberg have been examined. The regional differences in relation to climate change also influence the anticipated flood runoff figures.

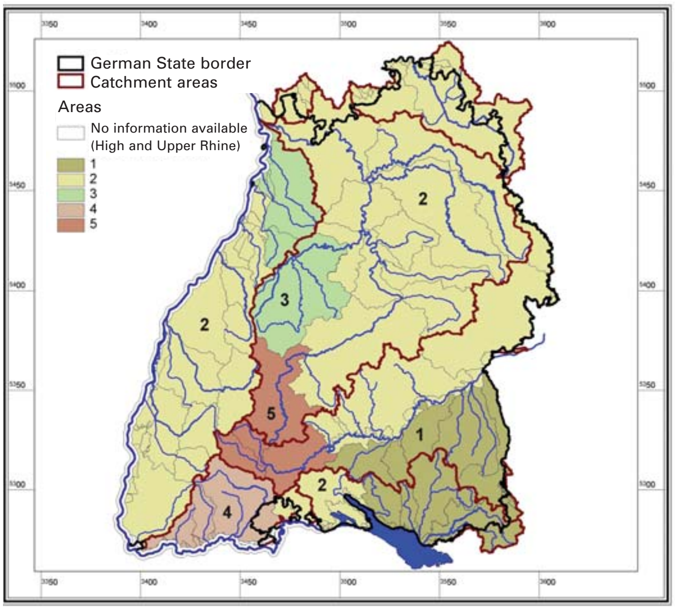
For instance, a climate-change factor of 1.25 was determined for the area of the Upper Danube. Minor and moderate floods will also increase. The runoff HQ_5 for a flood event that today occurs around every five years will increase by 67 percent in the Upper Danube. Consequently, for the future, the HQ5 value of the Upper Danube must be multiplied by the climate change factor 1.67. The climate change factor on the Upper Rhine for HQ_5 for instance is 1.45, and it is lowest, at 1.24, in the catchment area of Upper Swabia - Lake Constance.

In Bavaria, a climate change factor has also been introduced, as a global factor of 15 percent, for the statistical value of HQ_{100} on the basis of the investigation results at the time. This means that, even at this early point, the anticipated impact of climate change is generally being allowed for when planning new, government-financed flood defence measures. The basis for the climate change factor will be further developed on the basis of further investigations. This may also lead to a regional adaptation.

WHAT DOES THIS MEAN IN PRACTICE?

Example - flood barrier: the barrier will be constructed as planned, but a strip will be kept free on the outer side so that the dam can be increased in height easily if necessary.
Example - bridge: when planning a bridge, the regional climate-change factor is also allowed for since subsequent adaptation is hardly possible.
Example - embankment: in the case of a new embankment, the structure is designed to be increased in height subsequently if necessary with no difficulties.

CLIMATE CHANGE FACTORS IN BADEN-WÜRTTEMBERG



Climate-change factors $f_{(T,K)}$

T (years)	1	2	3	4	5
2	1,25	1,50	1,75	1,50	1,75
5	1,24	1,45	1,65	1,45	1,67
10	1,23	1,40	1,55	1,43	1,60
20	1,21	1,33	1,42	1,40	1,50
50	1,18	1,23	1,25	1,31	1,35
100	1,15	1,15	1,15	1,25	1,25
200	1,12	1,08	1,07	1,18	1,15
500	1,06	1,03	1,00	1,08	1,05
1000	1,00	1,00	1,00	1,00	1,00

Note: The factor is 1.0 for the repetition periods T > 1000 years

OUTLOOK

To date, KLIWA has primarily dealt with the problems relating to flooding. However, climate change will have other effects on the water balance. The forecast drier and warmer summers may bring with them periods of drought and consequently cause problems for farmers and inland waterway transport. The changed precipitation distribution will also impact on groundwater recharge and power station cooling, a factor that is important for the power industry. One other related topic is the trend in short-term precipitation (thunderstorms) bringing a great deal of water in a very short time and consequently causing local flooding to a greater extent. This is important for municipal drainage networks for instance.

The KLIWA Project that has been realised together with the German Meteorological Office (DWD) has given the German States of Baden-Württemberg and Bavaria an important instrument for identifying the need for adjustment measures and consequently ameliorating the effects of climate change on a regional scale.

But generally boosting climate protection measures in order to cut greenhouse gas emissions is just as important as adjusting flood defence measures. Even though the temperature rise will continue for the time being even if we were to stop emissions immediately, owing to inertia of the climatic system, each individual can still make a contribution towards preventing those who come after us from having to battle even greater problems.