Climate changes in the Rhine basin

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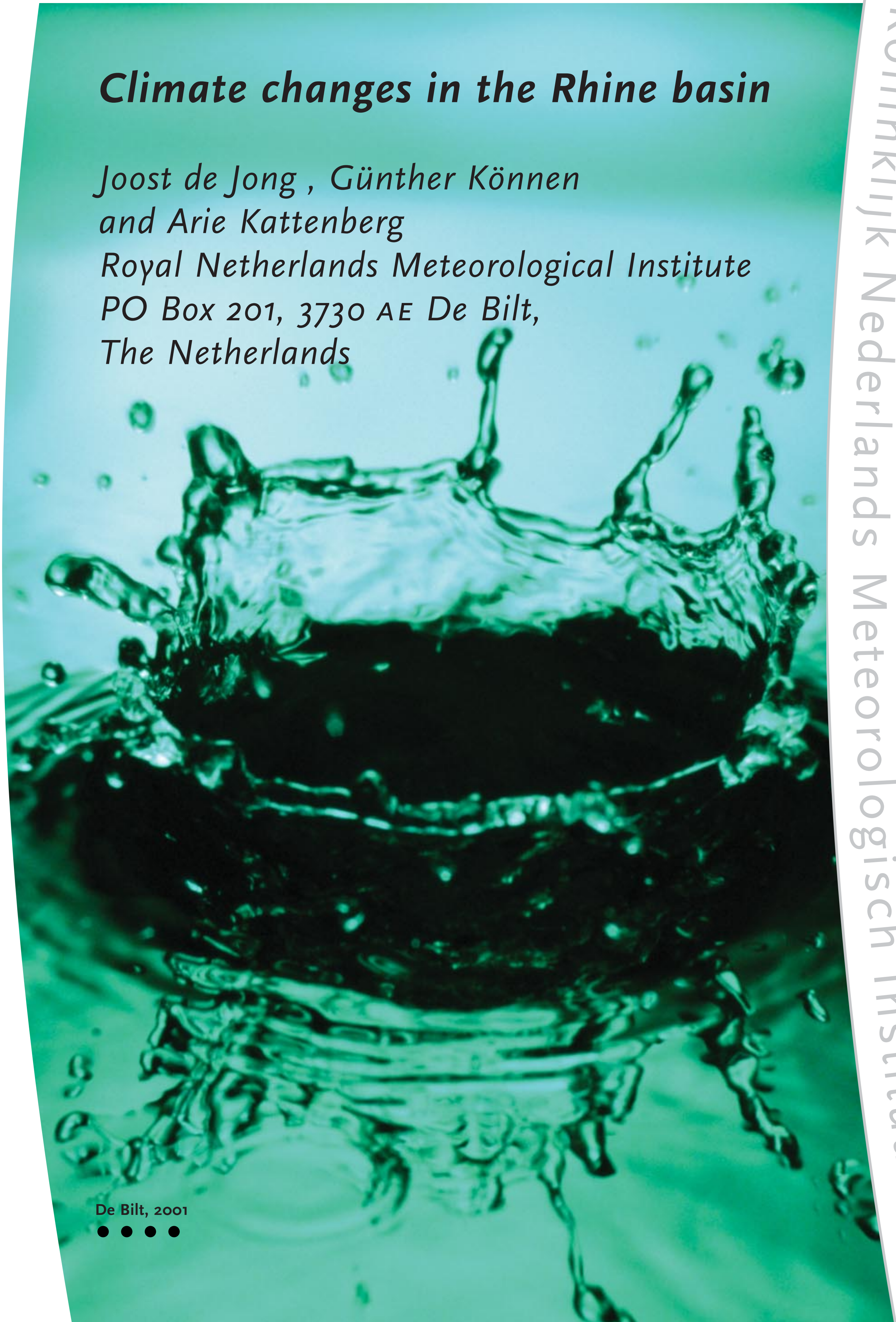

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Abstract

The long struggle to come from ad hoc and indiscriminate use or misuse of the river Rhine by locals and travellers towards the present integrated and internationally co-ordinated approach to the management of the river and its uses is described as a long and protracted mental climate change. In hindsight, this process was necessary to be prepared for the real climate change that we are currently experiencing. We describe how the river managers in the Rhine basin anticipate climate change.

Key words

River basin management, Rhine, Climate Change

Introduction

The river Rhine, which passes through many countries in densely populated Western Europe (see figure 1), and the history of its management provide an excellent example to discuss the challenges that climate change offers to river basin managers.

The global climate change that is taking place may soon speed up and intensify (IPCC 2001). The globally averaged surface temperature has risen by 0.6 degrees in the past century (figure 2) and is expected to rise another 1.5 – 6 degrees by the end of this century (see figure 3, from IPCC 2001). A warmer atmosphere will carry more water vapour and the hydrological cycle, with both evaporation and precipitation (on different locations and at different times), will intensify. Globally averaged sea level has risen by 10 – 20 cm in the past century and is expected to rise another 10 – 90 cm by the end of this century (see figure 4, from IPCC 2001). Sea level will continue to rise for several hundred years after greenhouse gas concentrations have stabilised and the total change will be in the order of meters (e.g. figure 5).

The prospect of these changes challenges all of mankind, also river basin managers. In the Rhine basin there is a high awareness of the 'climate challenge'. River managers are developing contingency plans based on commonly adopted scenarios and they are active and successful in placing these adaptive measures on the political agenda's in Europe. This relative preparedness of the river Rhine basin managers for the coming climate change is only possible because of a high level of transboundary co-operation and international organisation around the Rhine. This favourable situation arose only recently and the long struggle to obtain it was another, mental, climate change that had to take place in Europe before we could face the present, 'meteorological' climate change.

Below, we first describe the mental climate change that took place in the Rhine basin by sketching the history, the lessons that were learned and the current situation. We then recount what is known and expected concerning the present climate change and how climate change scenarios for the Rhine basin were developed. We finish this report by discussing what may be learned from our experiences and situation.

Mental climate change

The long struggle to come from ad hoc and indiscriminate use or misuse of the river Rhine by locals and travellers towards the present integrated and internationally co-ordinated approach to the management of the river and its uses can be seen as a long and protracted mental climate change.

History of the Rhine Basin Management

Due to particular hydrological characteristics of the Rhine basin (figure 1), this river became an important traffic chain in northwest Europe. Historically, in the early 19th century - because of the economical trade benefits- use of the river as a means of navigation received most attention and generated the most concern in the Rhine basin. It explains why the first international treaties between the riparian states favoured navigation interests. Later, in late 19th century, the Rhine states concluded conventions to protect fishery.

In the 20th century navigation, hydropower and pollution by the growing population, increased and intensified agricultural production and industry got a clear field. It seriously affected the Rhine ecosystem and brought other uses, such as drinking water supply, fishery, landscape, recreation, etc. in trouble. In 1950 Switzerland, Germany, France, Luxembourg and the Netherlands created the International Commission on the Protection of the Rhine, which was later on expanded with the European Commission. In the early years the Commission was not very effective in realising a reduction of pollution. The pollution came to a peak in 1971, when the water quality of the Rhine was so poor that it was inadequate to produce drinking water from the river water for months. In that time the river was almost depleted of oxygen.

Figure 1.
Northwest Europe and the river Rhine.

From 1971 onwards the mental climate in the riparian states is changing. Public and governments are getting more attention for the well being of the society. The riparian states decided in 1972 to stop and to turn the negative developments. Thanks to this climate change in politics, conventions aiming to reduce the pollution were concluded. The fire accident in Basle in 1986, which polluted the Rhine, led to a political wish to further reduction of the pollution and to decisions to rehabilitate the eco-system of the Rhine.

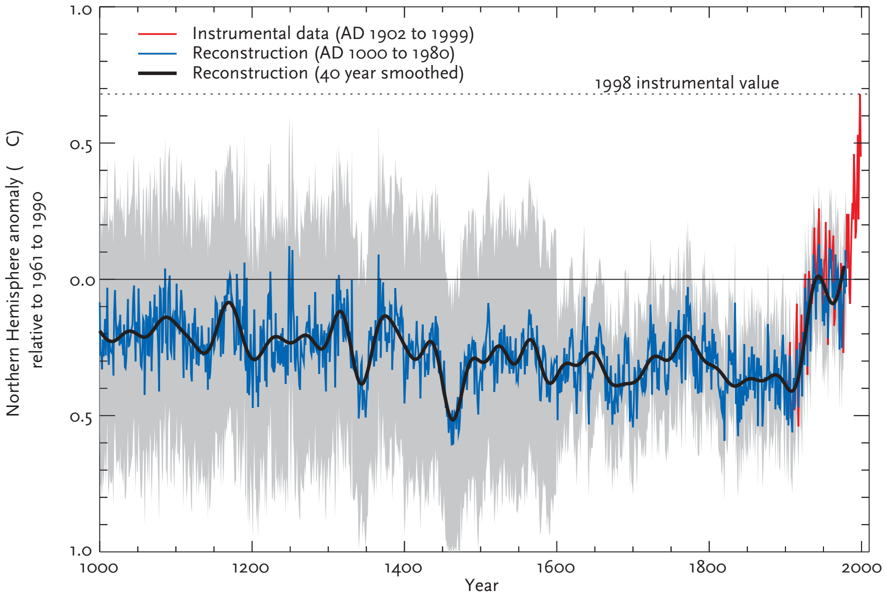
In 1995 heavy precipitation in the Rhine basin caused large inundation. The riparian states decided to tackle the flood problem together. Mutual understanding and trust between the riparian countries promoted this political climate change in the international co-operation. Legally defined harmonisation of river basin, land use and environment policy planning is important to reduce the pollution, to rehabilitate the ecosystem and to improve the protection against floods. The 1999 treaty about the protection of the Rhine provides the framework to realise these objectives basin wide.

Lessons Learned

Only voluntary decisions of riparian states have created the appropriate conditions for sustained international co-operation. Unilateral promotion of individual and sectoral interests must be avoided. Beneficial transboundary co-operation requires mutual trust, which takes time to be established. Concrete measures may confirm common intentions. Disasters with international impacts are excellent occasions to improve the transboundary co-operation. Harmonisation of measures must not be limited to the river itself, but should also include land use in the basin and the recipient sea. Legal frameworks help to tackle transboundary problems and to structure common activities. Common elaborated monitoring infrastructure considerably contributes to mutual trust, joint assessment and policy making. Periodical assessment of plans gives the opportunity to adapt and modify objectives and measures to changing conditions and opinions.

Climate change

Figure 2. Reconstruction of globally averaged surface temperature during the past 1000 years [IPCC 2001].



The surface of the Earth warmed about 0.6 degrees Celsius in the past century. Figure 2 shows how the recent warming stands out in reconstructed climate variations during the past 1000 years. The warming is also detectable in continental sized regions such as Western Europe, especially during the most recent decades. There is evidence that other aspects of the climate, such as snow cover or precipitation and evaporation, have changed also, both globally and locally (IPCC 2001). Global sea level has risen 10 to 20 cm during the past century. The most recent IPCC assessment of the state-of-the-art in climate research, stipulates that most of the observed climate change in recent decades is due to the enhanced greenhouse effect caused by extra CO2 and other anthropogenic greenhouse gases – and that more climate change is to come.

IPCC Projections

To make projections of future climates, IPCC developed a series of (35) 'possible' emission scenarios in a Special Report on Emission Scenarios, "SRES" (IPCC 1999). Based on these scenarios models project the globally averaged surface temperature to have risen by 1.5 to 6 degrees Celsius (relative to 1990) by the end of this century (figure 3). IPCC thinks it very likely that nearly all land areas will warm more rapidly than the global average, particularly those at northern high latitudes in the cold season.

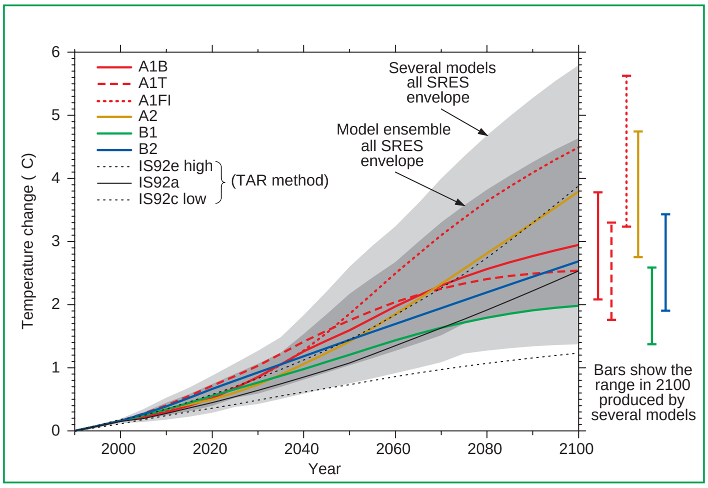


Figure 3. Projections of future global temperature from the IPCC TAR.

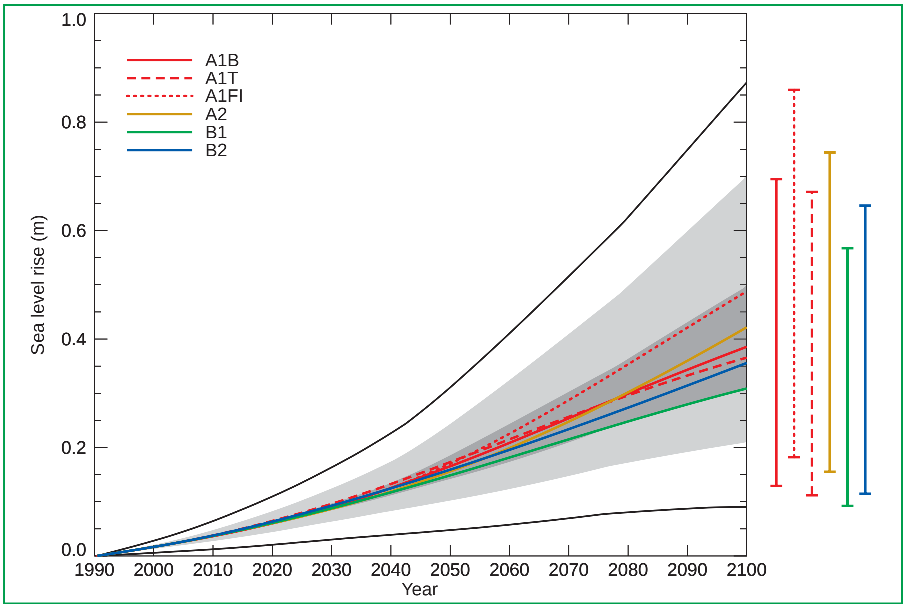
Global average water vapour concentration and, consequently, precipitation are also projected to increase during the 21st century. By the second half of the 21st century, it is likely that precipitation will have increased over northern mid- to high-latitudes (and Antarctica) in winter. At low latitudes there are both regional precipitation increases and decreases over land area in the models. Increase in precipitation will often be in more intense precipitation events (rather than longer duration). Larger year to year variations in precipitation are very likely over most areas where an increase in mean precipitation is projected. Increased summer continental drying (with an associated risk of drought) is likely over most mid-latitude continental interiors.

Regional Climate Change Scenario’s

Application of these projections and warnings to the regional scale – e.g. that of a river basin – is not without difficulty.

As is well known, climate models are far from perfect. Coarse resolution, imperfectly represented physics and relatively short simulations are inherent shortcomings. Assessments and analysis suggest that the models perform reasonably well for the long-term average surface temperature on global to continental scales. On a regional scale, however, or for processes that involve small scales, such as clouds or precipitation events we see that even the best models diverge from each other and give different or inconsistent answers. Even if the performance to describe the mean changes in climate on regional scales would be perfect, this would not be sufficient for the goal. The parameters needed are severe events, and the current climate models are far from describing those correctly, even for the present climate.

Figure 4.
Projections of future sea-level from the IPCC TAR



To bridge the gap between the climate models’ capabilities and regional information needs, we developed statistical methods to say something about possible future precipitation and about extreme weather events at a regional level, even though the climate models cannot.

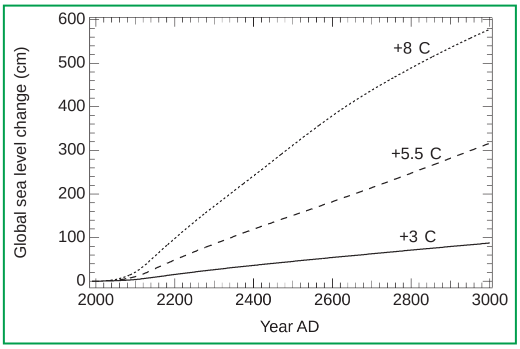


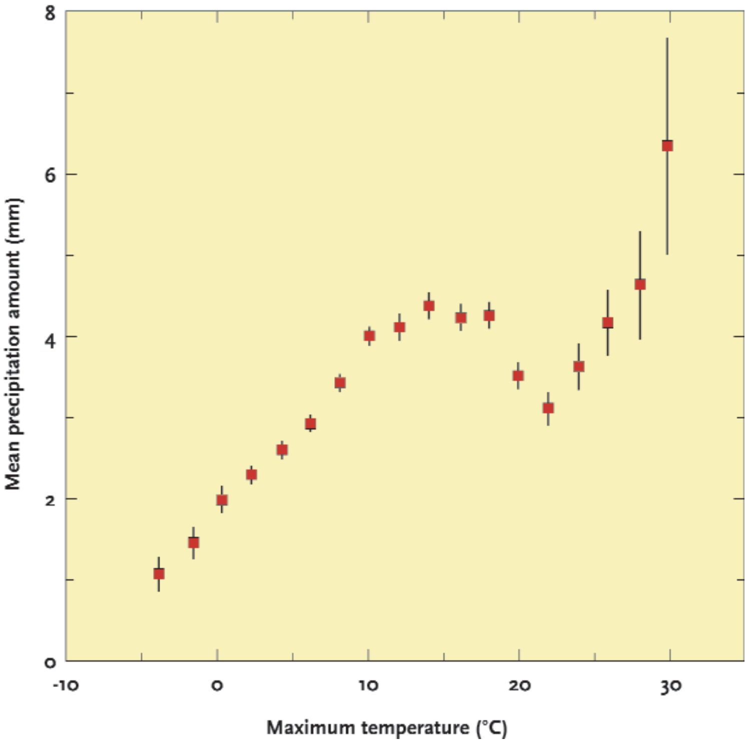
Figure 5.
Contribution from the Greenland Ice Sheet to future sea-level rise.

The statistical models use parameters that are considered to be reliably forecasted by climate models as predictors and the requested parameter as predictant. The outcome is a scenario in the real sense: a plausible solution for the required parameter that can be used to estimate the impact of climate change. It is meteorologically consistent, but it should be stressed that the scenario needs not to be true: under other assumptions, other solutions are also possible.

A simple example is a precipitation scenario that combines temperature projections for the large scale with the observed relation between actual local temperature and local precipitation and with the observed statistical properties of temperature. Observations show a distinct relation between local temperature and precipitation amount per wet day (threshold 0.1 mm) (see figure 6). The increasing part at the left-hand side of the graph is related with the Clausius Clapeiron relation between vapour pressure and temperature. It is the frontal rain that is described. The minimum is caused by the fact that the pressure is in that temperature range often high so that the vertical

motions are too weak to produce high rain intensities, while the temperature is still too low to cause deep convection. The heavy convective showers cause the steep rise at the end. They typically produce rain in the second half of the day.
Figure 7 highlights the properties of Fig. 6: by discriminating on the diurnal variability, it separates the convective precipitation from the frontal rain. The steep rise in the convective rain intensity corresponds to an increase of 10% per degree Celsius in intensity. This value is the same all over the Earth.

Figure 6. Observed relation between mean rain amount per wet day and maximum temperature for de Bilt, Netherlands.



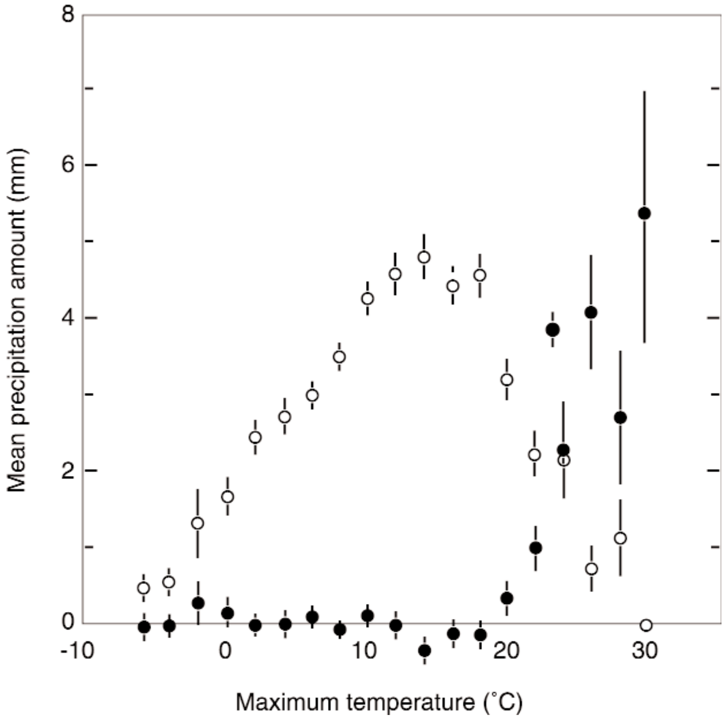


Figure. 7. Same as Figure 6, but now the amounts are split into frontal rain and rain that is caused by deep, surface-driven convection. Note that heavy convection starts only for days warmer than 20°C.

The technique to get a climate scenario that is useful for river management is to use Fig. 6 to transform an observed daily rain and temperature series into a series that might happen in a future climate. For this, first a guess from IPCC is applied to the temperature change DT. Then, for each day, a multiplication factor is derived from Fig.6 between the actual mean rain amount at the observed temperature T and a temperature T+DT. Last, the observed amount at that day is multiplied by this factor to transform it to a value representative for the future climate. This procedure is repeated for each day in the series. This method is illustrated graphically in Fig. 8. for a scenario that involves a warming of 3.7°C, with the additional assumption that this warming applies to every day of the series.
The result of this method is a time series of daily precipitation that could have occurred in the future world. The method described here uses the assumption that the probability for a wet day remains unchanged. By calculating the annual average of it and comparing it with direct model output, the plausibility of the method can be explored qualitatively. But the important benefit of the series is it daily resolution and the accompanying variability: the series describes (daily) extremes. Coupled with a hydrological model, it is potentially able to describe the change in statistical properties of high or low discharges.

The method outlined here, is a simple version of what has been developed so far. Other methods use more predictors and are more elaborated. In a similar 'hybrid' fashion, one can use existing knowledge about local extreme weather events and existing (long) time series of observation to produce scenario's for the statistics of extreme events in a changing climate. And the last development is a stochastic weather generator to produce long series of spatial correlated rain. It is found that such a generator is extremely

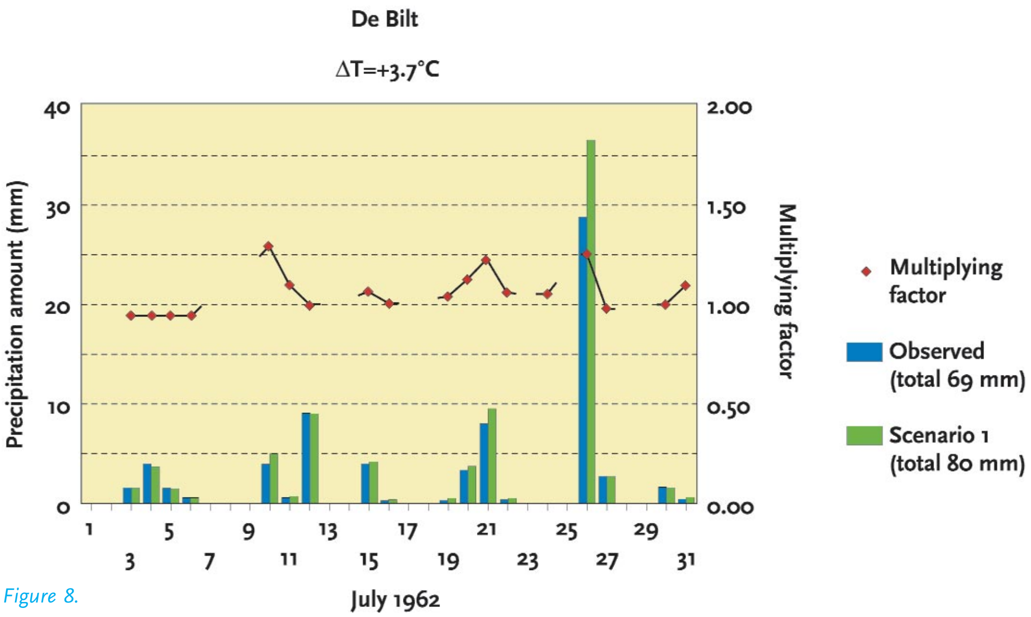


Figure 8. Transformation of a daily series into a series that is representative for a climate that is 3.7°C warmer than present. The observed series is of July 1965. The multiplication factor, derived from Fig. 6, is applied to the daily amounts. Note that in some cases the factor is smaller than one. The transformed series yield 11 mm more rain than the original series for that month.

useful to determine recurrence times of extremely rare events, even for the present climate. This tool, by a proper change applied to its variables, can also be tuned to a future climate.

It must be stressed that, even though such methods or their outcome may seem plausible, the outcome has large uncertainty margins. The predictions, usually 50-100 years ahead, are still useful for long-term planning of the dykes. A typical horizon for water management planning is 20 years. The scenarios serve the formulation of a no-regret policy for dyke design. As time proceeds, both climate and climate science will develop further and will result in new, more detailed and more reliable climate scenarios.

The Rhine Basin

Applying the methods described above, scenarios for climate change in the Rhine basin were developed. Based on the IPCC IS92 greenhouse gas scenarios (IPCC, 1996), in combination with the scenarios given by KNMI for the Netherlands (Können et al., 1997) according to the above described methods, climate scenarios for the Rhine basin as in table I were derived.

Sea level rise from thermal expansion of the ocean is expected to continue for hundreds of years after stabilisation of greenhouse gas concentrations (even at present levels), owing to the long time-scales on which the deep ocean adjusts to climate change. Also ice sheets will continue to react to climate warming and contribute to sea level rise for thousands of years after climate has been stabilised (see Fig. 5). Because of this, IPCC projects additional global sea level rise of a meter and more during the 22nd and 23rd centuries and beyond.

Table I: Climate change scenarios for the Rhine basin

	2050 central estimate 2100 lower estimate	2050 upper estimate 2100 central estimate	2100 upper estimate
Annual average temp.	+ 1 °C	+ 2 °C	+ 4 °C
#days with ice > 12 cm	- 34 %	- 60 %	- 85 %
Total annual precip.	+ 3 %	+ 6 %	+ 12 %
Total summer precip.	+ 1 %	+ 2 %	+ 4 %
Total winter precip.	+ 6 %	+ 12 %	+ 25 %
Intensity convective rainstorms in summer	+ 10 %	+ 20 %	+ 40 %
Prolonged winter precipitation	+ 10 %	+ 20 %	+ 40 %
10-daily cumulative winter precip. De Bilt	+ 10 %	+ 20 %	+ 40 %
Present recurrence time: 1 yr (= 61 mm) 10 yr (= 97 mm) 100 yr (=135 mm)	 0.7 yr 6 yr 47 yr	 0.5 yr 4 yr 25 yr	 0.3 yr 2 yr 9 yr

Table II: Adopted sea-level projections for northwest Europe

Projection (cm)	Unexplained part	Lower estimate	Central estimate	Upper estimate
2050	5	10	25	45
2100	10	20	60	110

(Unexplained part added into estimates)

Discussion and conclusions

The recent IPCC assessment demonstrates clearly that climate is changing and that the globally averaged surface temperature will rise by 1.5 to 6 ° Celsius. It is likely that land areas will warm more rapidly than the global average. Due to the higher temperatures global average water vapour concentrations in the atmosphere will increase, resulting in more precipitation, e.g. an increase in precipitation in winter over the northern mid-to-high latitudes, including the Rhine catchment area. In addition to the expected sea level rise in this century a further rise of up to a few meters in the next few centuries has to be expected.

Although there exists a gap between the global climate models and regional information needs, e.g. on the level of the Rhine catchment area statistical methods can help to bridge that gap. These techniques enable the development of scenarios for by example precipitation.

Such scenarios are useful tools in water management at catchment area level. They can be used in policy analysis to evaluate various policy options and to define no-regret measures in the whole of the catchment and the adjacent coastal sea area.

The present day's international co-operation of the riparian states along the Rhine offers a basis to cope with the challenges that have to be faced in the catchment area in relation to climate change. The new 1999 treaty on the protection of the Rhine provides the framework for international policy development, the political decision making and the joint implementation of works and the monitoring of policy implementation.

In summing up the following conclusions can be drawn:

- It is possible to bridge the gap between global climate models and the regional need for information e.g. for precipitation. Based on that scenario's can be developed upon which policy alternatives for the management of the catchment area of the river Rhine can be made and no-regret measures can be implemented.
- The political climate in the Rhine catchment area has changed in time in such a way that measures selected jointly by the riparian states will be implemented. The new treaty provides the framework therefore.

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