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WATER AND CLIMATE CHANGE: POSSIBLE CONSEQUENCES (3.2)

3.2.9 Global change and extreme hydrological conditions – Floods and droughts

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SUMMARY: Floods and droughts are natural phenomena which have become more abundant and more destructive than ever in many regions of the globe. Increasing levels of exposure and insufficient adaptive capacity are among the factors responsible for the rising vulnerability. The climatic mechanisms influencing hydrological extremes, observed in some areas and expected in future, are: increase in temperature, decrease in snow cover and ice jams, rising precipitation intensities and in some areas a decrease in summer precipitation. A complex interrelationship between the socio-economic domain, human impact on terrestrial systems and adverse effects of climate change are likely to increase the future risk of floods and droughts.

Floods and droughts are not exclusively occurring in modern times. Water-related extreme events have been a major concern since the dawn of human civilisation, without excluding any generation from danger for life, human or material losses. For example, during the 1990s of the 20th century, approximately one third of humankind, roughly 2 billion people, were affected by natural disasters, of which 86% can be led back to storms, droughts and floods. While flood related damages further increase dramatically, the 21st century is already now predicted to be an age of water scarcity. Therefore, the risks for extreme conditions in which water plays a central role appear to further increase in the future.

Actually, floods and droughts are comparatively rare events, and their occurrence apparently implies a random character. Careful time series analysis however reveals that cycles with a comparatively high sequence of extreme events can often be detected. Such phases then alternate with times of relative tranquillity, when no extremes occur. This behaviour can mostly be traced back to natural climate variability. Another common characteristic of floods and droughts is their global relevance – they occur in practically all climate regions of the globe.

A flood appears when appropriate meteorological conditions (e.g., high intensity rainfall) and pre-event characteristics in a catchment (e.g., high saturation degree of the soils) lead to the development of a surplus of water of such an extent that the normal river channel cannot convey the total water flow. The river bursts its banks, inundates floodplains or whole river valleys and causes damage. A drought can result from a long lasting precipitation deficit, possibly accompanied by weather conditions which favour an intensive evaporation of water, so that the already reduced water availability is further limited (Fig. 3.2.9-1). In contrast to floods may droughts extend in time for months, years or even decades. Droughts can also be distinguished from floods by their large-scale occurrence - they may strike large areas up to the sub-continental scale (several 100,000 km²).

Aspects of global change

Nevertheless, floods and droughts should not be viewed as exclusively physical or natural phenomena. Extreme hydrological conditions are often perceived as catastrophes only when they have adverse effects on the societies or the direct environment of humans. Therefore, the increasing vulnerability to floods and droughts is a complex interplay between climate variability and climate change and an increasing exposure against natural risks, with adaptation measures not able to keep up with this development. Hence, processes of global change not only include the man-made climate change, but also population increase, the loss of traditional adaptation strategies, changes in urban development, the economic growth in endangered areas, large-scale land-use change with its impact on the water balance of whole regions as well as technical measures along courses of rivers. Therefore, destructive floods and droughts always include social and economic components.

For thousands of years, people have settled in floodplains, attracted by the fertile soils, the flat terrain appropriate for settlements, the easy and safe access to water, and the possibilities of riverine transport. However, increased population densities, urbanisation and agricultural expansion in flood-prone areas have steadily increased the vulnerability to floods. In many developing countries, informal settlements spread over alluvial plains in an alarming degree. Poor migrants often flock to places vulnerable to flooding and where effective flood protection measures are not in place. In industrialised countries, a growing accumulation of wealth in flood prone areas enhanced the damage potentials of floods. In Japan for example, 70% of all property assets are concentrated in river plains which only cover ca. 10% of the national territory. An important factor in this context are technical measures of flood protection (e.g., the building of dykes or the straightening of river courses) which have often led to a false sense of security.

Droughts represent natural catastrophes of special

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complexity. Apart from their slow development which may mislead human risk perception, they can be characterised by their long duration. Droughts are frequently interwoven with economic crises or human catastrophes such as civil wars. The use of the available water resources has increased considerably over the last hundred years, twice as fast as the population growth. This makes clear that droughts are often only triggers of famines. The abandonment of nomadic lifestyles, overcultivation, overgrazing and no climate adapted irrigation measures lead to interactions between natural conditions and human water use which show most adverse effects during droughts.

Climate change and hydrological extremes

It is not an easy task to detect a climate signal in time series of hydrological extremes. Extremes are rare events so that long time series would be necessary in order to carry out reliable statistical analyses. However, long-time records of e.g. discharge which meet these requirements are mostly not available. An additional problem are the high temporal variations in many hydrological data which reflect the noise from natural climate variations and which may mask possible, long-term trends. Inhomogeneities in the observed time series are frequently caused by direct human impacts on the rivers and their catchments. They

pose an extra complication regarding attempts to detect a hydrological signal from climate change. It is also important to note that the global warming trend over the 20th century was preceded by the so-called "little ice age", a natural and very pronounced climate anomaly with relatively cold temperatures. Therefore, the hydrological conditions of the last few centuries were influenced by at least two different climate phases. A consequence of this development can be detected in the flood time series of some Central European rivers. They clearly show decreasing trends which can be traced back to fewer ice jam floods during the winter months - a clear sign of warmer winter conditions. However, also opposite developments can be identified even in neighbouring catchments (Fig. 3.2.9-2). This can be explained by catchment specific conditions which have a stronger effect on the regional hydrology than impacts of climate.

Generally speaking, the warmer the atmosphere the higher is the amount of water vapour which it can absorb. Indeed, observations confirm that atmospheric moisture is increasing in many places of the warming planet. In many cases this has led to increasing rainfall intensities and a higher risk for the formation of floods. For example, this development can be observed in extended regions of Central and Northern Europe. The atmospheric dynamics behind these processes lead to large-scale differences in the exchange of air masses, so that an increase in mean and peak precipitation in one region can lead to a related



Fig. 3.2.9-1: The development, the different types and the impact of droughts. Modified from a diagram of the US National Drought Mitigation Centre.

decrease in other regions. Hence, a reduction in annual precipitation totals has been observed in the already dry subtropical zones of the Northern Hemisphere. But also the summers in parts of Central Europe have become drier. Moreover, increases in intense precipitation have been documented even in some regions where the total precipitation has decreased or remained constant.

Droughts in Australia or South-east Asia with disastrous forest fires as well as heavy rains and floods in Southern Africa and in South America are often a consequence of the so-called El Niño events. These are climate anomalies which develop over the tropical Eastern Pacific when the near surface water is intensely warmed up. Since the mid 1970s, an exceptional increase and amplification of this phenomenon can be observed. Climate simulations could show that there is a potentially close interrelationship between the occurrence of El Niño events and climate warming. Another large-scale circulation pattern is the North Atlantic Oscillation (NAO) which especially affects the weather conditions over Europe. Observations indicate that the so-called positive NAO-



Fig. 3.2.9-2: Discharge gauges in Great Britain and related results from trend analyses for annual discharge maxima during the period 1941–1990. Increasing trends are marked with black circles, decreasing trends with grey circles. According to ROBSON & REED (1996), modified.

phase with a main focus of winter storm trajectories over Northern Europe has increased over the last 30 years, both regarding its temporal persistence and its frequency (HURRELL 1995). This involves higher winter precipitation over parts of Central and Northern Europe as well as drier conditions over Southern Europe. There is indeed a clear relationship between increasing winter precipitation and a remarkable rise in annual maximum discharges within the last 30 years, for example in the Rhine (BENDIX 1997).

MILLY et al. (2002) investigated flood events with recurrence intervals of more than 100 years in 29 large river basins of the world. They found that the frequency of such heavy flood events has increased during the 20th century. These findings are supported by data from BERZ (2001) which prove that the global number of large flood events during the 1990s was greater than the combined total of the three decades from 1950 to 1979. This development continued at the outset of the 21st century, for example during the year 2002, with destructive floods in China and many countries of Europe, among others the Elbe flood. The extreme heat wave and drought over Europe during summer 2003 has led to health problems, a high number of fatalities, considerable economic losses and large-scale forest fires.

The possible future

Statements related to future climate change have to be considered under the restriction that they are no forecasts but projections of possible developments based on scenarios on the emission of greenhouse gases and estimates of the future population and economic development. It is also worth to remember that there are – partially considerable – uncertainties coming from different results of the applied climate models (*Fig. 2.9-3*).

There is a high probability that a continuing climate warming will cause a higher climate variability, with an increased magnitude of precipitation events of high intensity in many locations, more frequent wet spells in winter in mid- to high latitudes and more intense storms. A number of studies assumes that the already observed increase in winter precipitation in the temperate climate zones of the Northern Hemisphere will continue (PALMER & RÄISÄNEN 2002). Climate warming will very probably reduce the importance of snow melt and river ice for the development of floods. Increasing winter precipitation together with increasing precipitation intensities - would then shift the major flood period from spring to winter, with concurrently increasing flood probabilities (Fig. 3.2.9-3). This development could affect major parts of Europe and North America. Scenarios from CHRISTENSEN & CHRISTENSEN (2002) indicate that large areas in Europe will be affected by increasing dryness during the summer



Fig. 3.2.9-3: Deviations (in %) between mean flood discharge MHQ determined by measurements and simulations using a hydrological model with measured (black bars) and simulated climate input, respectively. The simulated climate input comes from two Global Climate Models. The data represent annual maximum series generated from daily measured and simulated discharge. Selected time intervals are the years 1961–1995 (reference period) and 2061–2095 (scenario period). The data represented by the light grey bars show the assumed natural variability. Calculations were carried out for the gauges Neckar (a tributary of the Rhine river) and Emmerich (Rhine, catchment area approx. 110,000 km²). For more details see MENZEL et al. (2006).

months. At the same time, they project increases in the summer rainfall intensities, so that flood risk could also rise during the drier summers (KUNDZEWICZ et al. 2005).

A continuing increase of near surface water temperatures in the oceans could lead to intensified El Niño cycles and prolonged positive NAO phases, with the already described consequences regarding the occurrence of floods and droughts. MILLY et al. (2002) demonstrate that a strong increase in atmospheric greenhouse gas concentrations would lead to an enormous rise in the frequency of extreme floods in some of the investigated river basins. A today's 100-year flood could then occur every 2 to 5 years. Within the last 100 years, sea levels rose by 10 - 20 cm- mainly as a consequence of the thermic expansion of the warmer sea water - and they will continue to rise with increasing temperatures. This may lead to substantial adverse effects on low-lying lands and river deltas in flood prone areas. There will be probably an increase of storm surges and tidal flooding. The increase of the potential evaporation as a consequence of rising temperatures and the simultaneous reduction of summer rainfall could lead to increasing risks of droughts and heat waves in the centres of the continents and elsewhere.

Increasing dryness and the risk of forest fires

The dominating climatic control parameters regarding forest fires are the air temperature and the seasonal rainfall distribution. Dry and warm weather with high evaporation rates leads to reduced soil moisture and an accelerated drying of the vegetation canopy. All these processes trigger the occurrence of forest fires. The expected future rise of the air temperatures would therefore also increase the climatic forest fire risk. Persistent precipitation deficits and heat waves will increase this risk. However, a higher risk does not necessarily mean that the number of forest fires will actually rise. Investigations show that the frequency of forest fires is strongly dependent on human impacts (BADECK et al. 2004). Factors like appropriate forest management practices, the selection of suitable tree species, but also intention and gross negligence often exert higher influence on the fire risk than the fire disposition due to climatic conditions. Therefore, there will remain a number of prevention and adaptation options should the climatic risk for forest fires rise as expected.

Final remarks

The increasing vulnerability to floods and droughts can be considered as an interaction between climatic and socio-economic developments. The events of the recent past indicate that the exposure to floods and droughts increased at a higher degree as the adaptation potential. It is still difficult to detect a climate signal in hydrological time series and to issue clear statements about the future development. The indications compiled within the last years should however be sufficient to induce an overdue paradigm shift from a security culture to a risk culture ◆