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WATER AND CLIMATE CHANGE

The climate change research story has by and large been a narrative about temperature and carbon dioxide. Al Gore, the 2007 Nobel Peace Prize laureate, summarised in his Nobel lecture this way of looking at things:

So today, we dumped another 70 million tons of global-warming pollution into the thin shell of atmosphere surrounding our planet, as if it were an open sewer [...] As a result, the earth has a fever. And the fever is rising. The experts have told us it is not a passing affliction that will heal by itself. We asked for a second opinion. And a third. And a fourth. And the consistent conclusion, restated with increasing alarm, is that something basic is wrong. We are what is wrong, and we must make it right. (Gore 2007)

Most scientists seem to agree that the rapid increase of carbon dioxide in the atmosphere impacts climate developments, but this chapter argues that in order to understand the workings of climate and how society impacts it and is impacted by it, one should follow the multiple roles of water throughout nature and society.

It is the combination of two facts that makes it fruitful to follow how water moves through nature and society in order to understand both climate and its impact on societies and the intricate relationship between the two. Water plays a crucial role in the workings of the climate system and changes in climate in societies will first and foremost manifest themselves as changes in the way water runs in the landscape. This chapter will argue that the concepts of parallel and interlocking hydrological and hydrosocial cycles will prove to be useful for analyses of these relationships and processes and how they develop over the long term. These concepts should be regarded as additions to the three-layered water system, highlighting other aspects of relations between water and society.

WATER IN CLIMATE PROCESSES

The suggestion to 'follow the water' will be regarded by some as controversial and criticised for being 'anti-green', perhaps also representing some sort of climate change scepticism. For the 'green movement', putting focus on one element in nature may be seen as contradicting the aim and ideal that research on climate and climate change must study the climate system as a whole and the couplings between its individual components (see, for example, Bridgeman and Oliver 2006: 1). This holistic approach is based on the idea that it is necessary to avoid what has been described as the main problem in climate research: the practice of isolating individual climatic or atmospheric components. The aim of a holistic approach is therefore to understand the interactions of the physical, chemical, biological and human processes that jointly determine the conditions for life on the planet, that is, to carry out analyses within the framework of an integrated 'earth system'. It is argued that this approach has the virtue of recognising the complex interaction between components and links between the great systems of the earth and that it also makes it possible to analyse the ways in which humans affect climate through the socio-economic system (see, for example, Steffen 2001).

Climate is generally defined as the total experience of how weather and the atmosphere behave in a given region over a specified number of years (*Encyclopedia Britannica*). Because this topic is so broad, climate research has, however, in practice given priority to certain elements of the total climate system, for example, the role of the sun, ocean currents or wind, particularly temperature or, lately, one of the greenhouse gases – carbon dioxide. In contrast to climate research asserting that it studies the system as a whole and this system's relation to societies (the latter also often evoked in holistic terms), this chapter argues that this is practically impossible, and instead it favours a more modest but still very ambitious research programme: that of following the movements of water.

A focus on water may be seen by some as bringing the focus away from carbon dioxide and therefore being detrimental to the fight against global warming. But for some decades, developments in climatology argued that water dominated climate and that between 75 and 90 per cent of the greenhouse effect is due to water vapour and clouds. During the post-war years, the orientation of the climatology tradition moved away from parameters such as temperature and relative humidity towards measurements of flux. Climate, it was also gradually realised, could not be understood as a purely atmospheric issue, since it became evident that both its causes and its effects extend deep into the soil and the oceans.

Research became more focused on the transfer and transformation of energy. It was not air temperature *per se* but heat exchange that came to be

regarded as essential to an understanding of climate mechanisms. From taking snapshots of atmospheric data, the task became to understand the mechanisms involved in energy and moisture exchange. Various disciplines have now shown that the fluid element of water is *the* vital component of these mechanisms. The current debate on global warming and Al Gore's and IPPC's strong and almost sole focus on carbon dioxide as the only relevant greenhouse gas and on temperature as the most important issue represent a shift away from this tradition.

Here only some of the main factors that support the idea of following the water in climate research will be briefly mentioned.¹ Several useful volumes about how the atmosphere and the oceans transport energy around the globe are already available, and many of these fundamental physical processes need not be discussed here. The seas cover more than 70 per cent of the surface of the planet, and to an average depth of about 4 kilometres (Sarachik 2003: 129). So enormous are these amounts of water, that the oceans contain 80 times the amount of carbon dioxide stored in the atmosphere. About 5 per cent of the planet is covered by ice, or water in frozen form. The remaining 25 per cent of the area of the planet, normally classified as 'dry land', is crossed by rivers, dotted with lakes, populated with plants, trees, animals and humans that are mostly water. Beneath the surface of the earth and the ocean floor are enormous pools of groundwater (the amount of groundwater is estimated at 99 per cent of all fresh water in the world) that historically have only to a limited extent been part of the hydrological cycle but that now, due to a greater amount of pumping, increase the amount of water vapour. In the course of the past few decades, new and enormous aquifers, such as the Guarani in South America, have been discovered, and in the years ahead the world will be astonished by new discoveries of large 'water banks'.

The water that envelopes the earth is constantly on the move, in its own but still partly mysterious ways. On the continental scale, water is moved from the ocean to the land by winds and energy flows to the atmosphere and back to the sea. The circulation of water between the atmosphere and the oceans, of which precipitation is a small but essential part (it is roughly estimated that every year more than 113,000 billion cubic metres of water fall to earth, enough to cover all the continents to a depth of 80 centimetres), is very complex. It also involves continuous alternations in the phases of H₂O, from a liquid, to ice or vapour and back again. This hydrological cycle is a network of interactions between phenomena on scales that range from the millimetres of a leaf to the global, and timescales from seconds to millennia.

Water evaporates on average by about 1 metre a year, but since the oceans are 4,000 metres deep on average, most ocean water does not normally take part in this cycle (the *average* time that water spends in the

atmosphere is nine days, an indication of the fluidity of the system, while any given molecule of water may stay for thousands of years in the sea). Oceans are major factors in determining water surface temperatures and fluxes. The surface evaporation-atmospheric moist convection process, for example, is so strong at the Equator that it couples the atmosphere and the ocean into a single complex body that exhibits a continuous irregular joint oscillation known as the Southern Oscillation. In this process, water is the heat engine that powers atmospheric motion, thus continuously redistributing water mass and solar energy around the globe, while sweeping invisibly through the air in the form of water vapour and flowing across the surface of the earth as run-off. Water is thus not merely a passenger on the passing wind. To a great extent, water creates the movement of air or the breeze that transports it, and hence also regulates temperatures.

At any given time, about half the earth's surface is covered by clouds, which play a vital role in the hydrological cycle and radiation balance since they are nothing but masses of water droplets or ice crystals suspended in the atmosphere (Salby 1996). Clouds range in size from a few metres to hundreds of kilometres. Some regions are very cloudy, while others rarely see a cloud at all. Cloud formation, cloud characteristics and clouds' release of precipitation are key aspects of the rotation of water but also of climate in general. Most of the water in the atmosphere is in its vapour phase, converted to droplets or ice crystals depending on temperature and cloud physics. These fall out of the atmosphere as precipitation, and are replenished by evaporation from the seas and by horizontal and vertical transport within the atmosphere (Dickinson 2003: 124).

It is now undisputed: water vapour is by far the most prevalent greenhouse gas. There is about 60 times as much water vapour as CO₂ in the atmosphere. Also the Intergovernmental Panel on Climate Change (IPCC) acknowledges that vapour accounts for somewhere between 60 and 70 per cent of the greenhouse effect. This has made sceptics question that global warming can be caused by increased amounts of CO₂; since water vapour is the most potent greenhouse gas and is created through natural evaporation rather than human activity, current warming trends are nothing to worry about. But this viewpoint is also too simple: it overlooks the reactive nature of water vapour. The amount of vapour the atmosphere can hold is to a large extent a function of temperature, since the warmer the air gets, the more water it is able to collect.

All also agree that water vapour is a very efficient greenhouse gas and more effective at absorbing the thermal radiation from the earth's surface than carbon dioxide. Incoming short-wave radiation from the sun is let in, but water hinders the longer-wave radiation from leaving earth. There is a maximum quantity of water that clouds can hold before they become

saturated, and this process increases approximately logarithmically with increasing temperature (Ward and Robinson: 15). Water, clouds, evaporation and precipitation are thus very significant, but at the same time there are also great uncertainties regarding both measurement methods and the data they produce (Goody and Yung 1989; Hartmann 1994; Lindzen 1996; Kiehl and Trenberth 1997; Held and Soden 2000; Trenberth et al. 2009).

Computer modellers of climate change have, however, tended to overlook or reject the role of water vapour. Some include the positive feedback effect, but although crucial, it is not the most important way in which water is involved in the climate system. The changes to the hydrosocial cycle due to the radical increase in anthropogenically produced water vapour as a result of watering and transpiration losses from farming and gardening, from canals and artificial lakes, from the burning of oil and gas, and losses of water pumped from aquifers, also impact the hydrological cycle and thus global distribution of humidity. The fluctuations in the water vapour content can therefore not be reduced simply to temperature fluctuations. Irrigation and large water projects, such as the South to North Diversion Project in China, the Aswan, the Renaissance and Meroe Dams on the Nile, the taming of the Colorado River and the pumping of large underground aquifers affect the humidity not only in the immediate vicinities of the fields, but far away.

The importance of water in regulating climate is now undisputed, and a growing number of studies confirm its centrality. A typical example is a study published in *Nature Geoscience* (19 January 2014), which shows that during the abrupt cooling at the onset of the Younger Dryas period, 12,680 BP, changes in the way water cycled were the main drivers of major environmental changes in Western Europe.² The article argues that the intrusion of dry polar air into Western Europe led to the collapse of local ecosystems and resulted in widespread environmental changes. It also suggests that future climate changes will largely be driven by hydrological changes, not only in the monsoon regions, but also in temperate areas such as Western Europe. It has also recently been argued that human modifications of local hydrological cycles have altered the hydrological cycle in far-off places. Due to irrigation and deforestation in Asia, regional changes in water vapour patterns there changed rainfall patterns in Africa (Gordon et al. 2005). The theories of why Ice Ages happen are many and often contradictory, and none are satisfactory. The extraterrestrial theories – that something happened in our solar system or the Milky Way or even on the sun to start an Ice Age – do not concern us here, but the ‘terrestrial’ theories allocate a central role to water. Although the ‘snowball-earth theory’ has met strong opposition, most other terrestrial theories do give the hydrological cycle and changes in it an important

explanatory role. Moreover, it is widely assumed that the behaviour of it has largely created and affected the glaciation periods during and between the Ice Ages. Temperature, as compared to water, is a way of estimating climate development and change, but it is not in itself a 'force'.

Between 75 and 90 per cent (although pinning down the exact contribution is very difficult if not impossible) of the greenhouse effect is caused by water vapour and clouds. The jury is still out, however, on the respective roles played by water vapour and carbon dioxide in causing global warming, but evidence points to oceans and the water cycle as being stronger than the effects of CO₂. To suggest that carbon dioxide decides the water cycle is like claiming that the tail wags the dog. But no matter what conclusion the scientists draw on this issue, there is general agreement that the water cycle is absolutely crucial in climate processes.

The fundamental role of water in defining and classifying climate in societies is expressed in the fact that most climate classification systems are largely based on the criteria of local and regional or continental differences in the water cycle. Wladimir Von Köppen's pioneering model for climate zones was based on the concept that native vegetation is the best expression of climate, but this in turn was founded to a large extent on average annual and monthly precipitation and the seasonality of precipitation.³ C. W. Thornthwaite's influential climate classification method monitored the soil water budget using evapotranspiration or the proportion of total precipitation used to nourish vegetation over a certain area.⁴ In spite of all this, our knowledge of the workings of the water cycle is still surprisingly defective.

For example: we do not yet know how much rain actually falls on earth (it could be as much as twice as much or as little as half of typical estimates). We do not know the amount of evaporation. We do not yet know how clouds function or the roles of ocean currents. Measurements of amount of and changes in water vapour in the atmosphere are very difficult to make and the data are therefore basically little more than guesswork. The same holds for summary measurements of spatial and temporal variations in patterns of precipitation. Many comparative data sets are unreliable and not very extensive, partly due to changing measurement methods and because measurement programmes in most countries are quite recent. It is also difficult to identify the causes of changes in precipitation, since we do not know much about the role of crucial cloud systems or how and why they change. Even river run-off data are scarce and in many parts of the world erratic, and in most areas systematic registration of river flows started no more than 100 years ago; even now, in some countries many rivers are still not measured systematically.⁵ In some of the biggest and therefore also climatically most vital river basins such data are kept as national secrets for reasons of 'national security'.

The main loop of the hydrological cycle, the web of interactions between fresh water and the oceans, has scarcely been studied at all, and we still know little about how fresh water affects ocean currents, temperature and evaporation (cf. the proposal to dam the Strait of Gibraltar to prevent a new Ice Age because studies of the effect of the High Aswan Dam on the Nile suggested that changing the outflow of the Nile had altered the currents in the Mediterranean and the direction of the Gulf Stream in the Atlantic Ocean would change! [Johnson 1997], or the published plan to dam the Baltic in order to send fresh water to what is expected to become a much drier Southern Europe). The difficulty of observing and estimating the interactions between rain, plants and soil moisture is obvious.

A number of different disciplines have studied different aspects of water, but there is no tradition for following the water. Hydrologists have studied the movement of water through the soil and subsoil and in streams and in natural storage sites such as rivers and lakes. Stratigraphers and sedimentologists study the finished products at the site where they are deposited by water, while engineers, hydrologists and geomorphologists are concerned with the source area, the river network or the basin structure. Oceanographers have dealt with oceans, and meteorologists and atmospheric chemists with water in the clouds and in the atmosphere. Hydrometeorologist study the long-term aspects of the hydrological cycle, while plant physiologists investigate the process of transpiration and glaciologists the formation and dissolution of water in the form of ice. Soil physicists have the moisture characteristics of soils as a major concern. In spite of the fact that water is marked by being in constant flux and having no absolute boundaries, research has in general been compartmentalised.

There are still huge gaps in our knowledge of the most basic facts about water. There are no reliable global maps of precipitation and evapotranspiration, or evaporation from the seas, or of aquifers beneath the ocean floor or beneath the surface of the soil. Elaborate models of different spatial or topical aspects of climate and of the hydrological cycle are therefore often mathematical constructs rather than descriptions of the real, complex movement of water from one sphere to another. Data have been accumulating (see, for example, Huntington 2005), but we still know very little about crucial aspects of how this greenhouse gas functions (see Burroughs 2007: 247–56 for an overview), and, by implication, we also know rather little about climate and what precisely drives climate change.

CLIMATE, WATER AND SOCIAL PROCESSES

A focus on water in climate processes is also crucial from another point of view: that of society. I have earlier called the era we are living in ‘the

age of water insecurity' (Tvedt 2007). The reason is that the uncertainty about how water will behave in the near and long-term future will structure the public discourse about potential futures and fundamentally inform economic decisions and institutional choices, and impact personal world-views.

What constitutes the 'newness' of this new era is not that water in societies is distributed in new ways or that it is possible or rational to talk about a 'novel climate' as some researchers do. The historical facts are clear: fluxes have always characterised water as a natural phenomenon. What is new is the emergence of a *social fact* related to our understanding of climate that is both of fundamental importance and has never been experienced before.⁶ For the first time in history, people in general have become aware of the fact that the hydrological cycle has dramatically changed in the past. It is no longer possible to assume that sea levels, glacial cover, river discharges and rainfall patterns are static back-drops to human civilisation. The new uncertainty about the future of humankind is paradoxically resting on discoveries about the history of water in nature, such as the Arctic's tropical pre-history, and the fact that the Sahara after the last Ice Age was a green oasis with large rivers. It is no longer possible to assume that the water landscape might not dramatically change and challenge the survival of most societies.

It is these uncertainties about water in nature and in human societies that now quite suddenly have become a social and political reality and, importantly, they will remain so. This is because it will always be impossible to predict with certainty what the changes in the water cycle will be, at the same time as even small changes in the delicate balance that many societies have established between water and themselves will have far-reaching, often structural consequences. This uncertainty paradox will lead to a situation where major political struggles will be fought not only over the control of water resources but increasingly over projections of the future of water. Differences in ideas about what this future will look like and the most appropriate ways of dealing with it will be a highly divisive issue, and of a new kind.⁷ For example, will few people become more powerful than those who manage to locate their projections of the future waterscape on the 'throne' of public discourse? If everybody believes that the water cycle is created by man, societies will be increasingly vulnerable to apocalyptic and fanatic creeds, and this might eventually lead to all sorts of despotism and anarchy.

Since water is absolutely necessary in all societies and plays both a structural and structuring role, changes in the way it moves on global and local scales will have all kinds of consequences for social development (changes in precipitation will impact on everything from urban drainage

systems to patterns of tourism, as changes in river discharges and run-off will affect reservoirs, irrigation, fishing, tourism, transport, ecology, oceans, etc.) in all societies. These changes in how water flows in nature and society will also question the climate classifications themselves.

There has been a rapid rise in the number of studies and research programmes with titles like 'climate change' and 'human adaptations', and so on. However, much of this work tends to miss or gloss over a fundamental conceptual problem: the term 'climate change' is too general for use in connection with empirical data or knowledge of social impacts and adaptation. The IPCC defines climate change as: 'Climate change in IPCC usage refers to any change in climate over time, whether due to natural variability or as a result of human activity.' The term thus includes virtually everything, and empirical study of the social impact of 'everything' is not possible. Analyses of the 'impact of climate change' have therefore either tended to be very general and difficult to verify, or have in practice dealt with only certain aspects of climate and their impact without explicitly justifying the actual focus, thereby making attempts to falsify results difficult, and comparative research impossible.⁸ Instead of focusing on the social impact of climate change in all its aspects, research should concentrate on only certain features.

Another argument in favour of such more moderate ambitions is that very few people were doing research on such topics before the 1990s, and that the field therefore is in its infancy. The 'climate change' question is both extremely broad and rhetorically very powerful, and such a mix of politicised, imprecise concepts makes it even more crucial to encourage research with findings that can be falsified. A paradox is therefore at work: the broader the focus, the more difficult it becomes to study the interactions between societies and nature or climate. The proposal here is instead that it would be more realistic and more fruitful to study the role of and changes in the hydrological cycle and how these impact on societies, and how social responses again impact on the water cycle.

There are several reasons for narrowing research in this way. All researchers agree that climate change will also because of feedback mechanisms be clearly and directly reflected in the way water flows in nature and societies. This understanding is also reflected in popular perceptions of what changes in climate will mean to societies. People all over the world are ever more often asking questions such as: Are we living in an era that will bring more rain and floods, or more dry spells and droughts? Will the sea level really rise, and if so, how much? Will the glaciers melt and finally disappear because of global warming, or will they remain the same, or will rivers freeze and glaciers even grow because of a new 'Little Ice Age'? There are predictions that the already highly uneven distribution of water might increase, and that some areas will face

increasingly severe water stress. Can we expect mass migration from poor dry areas to more water-wealthy areas and an exodus from dry inland areas to the more humid coastal areas? Water managers are realising that they must adapt to an undefined future and can no longer rely on a hydrology based on simple stochastic predictions.

The changing appearance of water in society has already created what are the most fundamental periodisations of world history: the many Ice Ages. When the last Ice Age peaked 18,000 years ago, the mean sea level was about 120 metres lower than it is today, which had a profound impact on settlement patterns and most other social issues.

Some general consequences of changing water are well known. If the form of water changes and more ice melts, the oceans will expand and thus increase coastal erosion and salt water intrusion in coastal aquifers. Densely populated delta areas and estuaries and low-lying megacities will be threatened, and the general migration pattern from inland areas to coastal land, one of the most fundamental historical processes in our time, will be affected. More moisture will be sent into the atmosphere in the tropics, which will generally accelerate fresh water transport to higher altitudes, which in turn will lead to increasing precipitation in many places and to more extreme events related to land-surface hydrology in others, producing both more floods and more droughts. The subsequent changes in soil moisture will have a huge impact on food production, since soil moisture is a crucial factor in agricultural production. The stability of whole food systems may be at risk,⁹ and global migration patterns will be influenced on a grand scale. The relationship between snow and rain will change, with immediate and far-reaching economic consequences.¹⁰ Whether precipitation falls as snow or rain fundamentally affects economic activities and social life, especially in the mid- and high-altitude countries of the world. In the subtropics, climate change is likely to lead to reduced rainfall in what are already dry regions. The overall effect will be an intensification of the water cycle that causes more extreme floods and droughts.¹¹

Since this book has suggested a long-term view of human history where a very central and universal aspect of it is how human societies have evolved by adapting to and exploiting varying niches created by the co-evolving of different waterscapes and societies, changes in how water runs on the planet and locally will have far-reaching implications. Physical water systems enabled certain types of vegetation, and encouraged certain economic activities and even world-views. Rivers have always impacted on settlement and urbanisation, in some cases providing inland transport routes and access to the sea (almost all the capitals of Europe are located on the banks of rivers). However, the assets of such locations historically can be a liability and in an era of growing uncertainty about

the future of water this is especially so. Humans' relationship with water is highly susceptible to damage caused by climate change, due to already established delicate balances and niches.

Contrary to common belief, modern societies have not liberated themselves from the power of water, although modern technology has to a large extent liberated society from the tyrannical, locational power of water. Most people in the world live in a river basin and more than half of the world's population lives in river basins shared by two countries or more. Some of the riparian systems in dry areas play an absolutely crucial role in the life of societies, and they are particularly vulnerable to changes in precipitation patterns due to their high levels of exposure and sensitivity to this type of climate stimulus, while others will display strong resilience. But in general, riparian systems are likely to become what we might call 'adaptation hotspots',¹² as will coastal deltas and cities due to the expected sea level rise. Research on potential impacts of climate change should therefore also for these reasons follow the water.

The implications of changes in the water cycle's impact on society, compared to that of temperature, wind, and so on, can be studied empirically in many locations, since the changes are easily identifiable and measurable (amount and type of precipitation, evapotranspiration, run-off, river discharges, sea level rise, and so on). They can also be studied comparatively, since all societies share social experiences with changing waters. Moreover, different environments, such as wetlands and prairies, snowfields and deserts, river valleys and river deltas, exhibit different regimes of precipitation, evaporation and stream flow, and each therefore presents different challenges, benefits and threats to which societies have adapted and managed in one way or another. Following water also makes it easier to describe and analyse how different societies and parts of society react differently to changes in the climate.

One premise of the argument that it is necessary to focus analyses of the impacts of climate change more narrowly is that the real world of climate and its impacts in society is so complex that it is essential to isolate parts of this reality for analytical and empirical purposes. Another is that this necessary decomposition of climate into more simplified structures for analytical purposes should not be accidental, pragmatic or implicit. This chapter has put forth arguments for why a focus on the hydrological and hydrosocial cycles can be a fruitful decomposition of this broader reality. The ultimate aim of such a research strategy will be to link these simplified structures so as eventually to become able to describe and model the totality of climate and society/climate relations, since it is a truism that the real world is continuous, and isolated structures are always artificial, 'invented' facets of reality. The selected water-system approach should be complex enough to produce a high degree of internal coherence, so

that studies will yield significant and useful results. At the same time, the approach is simple enough for comprehension, comparison and empirical research. To study the two notions of water cycles in conjunction addresses multiple concerns and therefore also enables analyses of a hierarchy of an organised, interlocking set of systems.

AN ANALYTICAL APPROACH AND A PAIR OF CONCEPTS

There can be no doubt that dominant social science has basically been uninterested in the hydrological cycle as a natural, physical phenomenon of relevance to our understanding of societies and development trajectories. Recently it has been suggested that the concept of the hydrological cycle should be discarded altogether, because it should be seen as a technical, natural science concept; as a concept of the 'hydrologists' or water planners, and on this basis rejected ontologically. The concept should also be discarded on epistemological grounds, since it is argued that the hydrological cycle no longer exists. Humans affect it to the extent that it should rather be renamed. For both these reasons the term hydrological cycle should be substituted by the term 'hydrosocial cycle', it is argued. This book firmly maintains, however, that the term hydrological cycle is very fruitful from a natural and social science point of view. It has proved its usefulness in understanding climate and the behaviour of water as part of the earth system, and in managing water in societies. It retains natural processes as a factor in social development and it acknowledges the role of the hydrosphere and water in the climate system.

The term 'hydrosocial cycle' as used here should not replace the term 'hydrological cycle'; on the contrary, it is in contrast to and in relation with the latter concept that the term 'hydrosocial cycle' acquires its identity, meaning and relevance. The 'hydrosocial cycle' does not imply that the hydrological cycle itself has become 'social' or that it is no longer 'natural'. Rather the use of the two concepts focuses on parallel though interacting processes that in the long run can be seen as a non-dialectical relation where they impact on each other and are impacted on by each other. The hydrological cycle is the fundamental and most powerful cycle in nature but it both impacts on and is impacted on by the hydrosocial cycle. The latter focuses on how water travels through societies and establishes a comprehensive framework for analysing its entire route through societies, and also how it impacts on the hydrological cycle over time and in place. It will also enable analytical integration of another social fact: from a social perspective there are many different water cycles in nature, and the hydrological cycle cannot be understood outside of the social. The implications of only talking about the hydrosocial cycle will

be that all forms of development will be reduced to outcomes of human action, and human action only, as if the natural workings of the Niger delta and the cloud systems over the North Sea have no social relevance any more or should be reduced to a social fact and variable.

In order to understand how climate and society are impacted on by water and how water (and nature) impact on society, we need to study both the hydrological and hydrosocial cycles and how they interact and relate to the rest of the climate. The movement of water in nature is impacted on by its 'social experience', and it is a truism that the water cycle is always understood through certain social filters. Since societies have developed through interacting with their waters, it is necessary to study both the physical aspects of water as part of the entire climate system and the water landscapes modified and conceived by human beings. This pair of concepts also underlines the fact that the object of study is the same water since its character does not change whether it is observed in the hydrological or hydrosocial cycle, only its role in nature and its relationships to the human world do.

In order to be able to meet the challenges of the future waterscapes, we need to understand past interactions between water and society, not because they can yield any simple solutions for tomorrow – history never does – but because they broaden our understanding of what is possible. Because water is of fundamental importance in all societies, it can be regarded as a kind of talisman for the continuity and deep structures of history and human evolution. All climate changes in the past have been manifested in changes in the water cycle. The migration patterns of hunter-gatherers were affected by where they could find water, and their routes were fundamentally affected by changes in the waterscape, such as the retreating glaciers in Scandinavia and the disappearing rivers of the Sahara. The settled agricultural civilisations on or near riverbanks in Asia and the Middle East were vulnerable to changes in precipitation and river discharge, as the position and spread of the story of the Great Flood testify. For a long time, the collapses of the Indus, Sumerian and Mayan civilisations were simply seen as the outcome of cultural decadence or of foreign invasions and attacks. Now we know that these factors are not sufficient to explain why these civilisations disappeared. Research has established that the fate of the Mayan civilisation was also affected by changes in the in the hydrological cycle; and that recurrent droughts in around 800 weakened the economic base and cultural position of the Mayan leaders who led a rain-based, agricultural civilisation in a seasonal desert environment. We now know that the Indus suffered from bad years and from great floods and that tributaries like the Beas River migrated away from the civilisational centre, Harappa; more recently, it has been argued that the fall of the Chinese dynasties was caused

by failure of the monsoon, just as researchers have previously argued that Egyptian dynasties crumbled due to successive bad Nile years.¹⁴ The causal relationships between changes in the water cycle and social impact might have been more complex and less unidirectional than these interpretations suggest, but there is no doubt that changes in climate and the hydrological cycle weakened those civilisations. Everybody who is unaware of the waterscapes and their transformations in the past is doomed to misunderstand the future, and politicians and planners will not manage well the future challenges of changing water cycles if they do not know anything about how societies have adapted to past changes in waterscapes. It is therefore imperative to develop further what is here called a hydro-historical approach.

Research into the history of water-society relations might improve our knowledge about changes in the hydrological and the hydrosocial cycles and also about past interactions between climate and society. Chronicles of religious centres and books of kings and rulers have recorded water-related events due to their importance for societies, and more and more attempts will be made by different natural scientists to reconstruct past river discharge profiles, flood and drought occurrences, severe frosts and heavy snowfalls, employing different sources and methods, from satellite images to pollen analyses. The growing feeling of uncertainty also requires new perspectives, approaches and methods of research on modern society. The genie – our uncertainty about the future waterscape – is out of the bottle and can never be put back. Since we are living in an era marked by these uncertainties about water it will be more important than ever to understand how societies and water interact. The complex roles of water in societies and the links and feedbacks between water in nature and in the human world have become for good far more than an issue of merely academic interest.