CHAPTER 8

THE PHYSICAL SCIENCES AND CLIMATE POLITICS

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1 ORIENTATION

In the following sections, the physic-ness of climate science is discussed. One of the motivations for doing so is related to the observation that some scientists, trained as physicists, often play a very influential role as political actors, when interpreting and explaining the significance of scientific insights for policy implications using the 'linear' model, according to which knowledge leads directly to first political consensus and then decision making, while social and cultural processes related to preferences and values represent mostly invalid disturbances (e.g. Beck 2010; Curry and Webster 2010). Of course, the linear model means that those in control of the knowledge ought to be in control of the outcome of the political decision process.

We therefore thought it meaningful to examine to what extent this claim of political competence is warranted. We find that it is not. In order to become societally relevant, climate science has to become trans-disciplinary, by incorporating the social-cultural dimension.

We could also have done an analysis with fields related to ecology or economics. A similar phenomenon is also observed among some high-profile members of these groups; that scientists find it difficult to balance the authority of scientific competence, limitations, and integrity with the need to engage one's own values. We limit ourselves here to physics, first because this field is likely the most important.

Our chapter features three main sections.

In section 2, we discuss the historical development of the concept of climate leading us from an anthropocentric view to a strictly physical world-view, and one that is now moving once again towards a more anthropocentric view—this time concerning not only the impacts but also the drivers. This is not meant as a general review of the history of climate sciences, which is done competently by Weart in this volume. Instead we want to emphasize the circularity in the development, from an anthropocentric view, over an impassionate, distanced truly physical view, back to an anthropocentric view.

In section 3, a series of physical issues, from modeling, over parameterizations, the impossibility of experimentation, and data problems are discussed.

In section 4, the concept of 'post-normal' science is introduced, which is related to high uncertainties in the field of climate research, and the high stakes on the societal side. Here, at the boundary between science and policy, new dynamics emerge, which have little to do with physics; dynamics which depend on culture and history, on conflicting interests and world-views.

A brief concluding section argues for the need for a trans-disciplinary approach to climate in order to assist in developing policies consistent with physical insights and cultural and social constraints.

2 History of Climate Science

Historically, 'climate' was considered part of the human environment. Alexander von Humboldt ([1845] 1864: 323–4) in 1845 in his book *Cosmos: A Sketch of a Physical Description of the Universe* defined climate as the sum of physical influences, brought upon humans through the atmosphere:

> The term climate, taken in its most general sense, indicates all the changes in the atmosphere, which sensibly affect our organs, as temperature, humidity, variations in the barometrical pressure, the calm state of the air or the action of opposite winds, the amount of electric tension, the purity of the atmosphere or its admixture with more or less noxious gaseous exhalations, and, finally, the degree of ordinary transparency and clearness of the sky, which is not only important with respect to the increased radiation from the earth, the organic development of plants, and the ripening of fruits, but also with reference to its influence on the feelings and mental condition of men.

Thus, like astronomy, climate in much of nineteenth-century discourse was subject to an anthropocentric view. The global climate was little more than the sum of regional climates (cf. Hann 1903), and the challenge was to faithfully describe regional climates by measuring and mapping the statistics of their weather. Not surprisingly, a large body of information was generated, dealing with the impacts of climate on people and societies. It was the time of the prominence of the perspective of climatic determinism (Fleming 1998; Stehr and von Storch 1999, 2010). At the turn of the nineteenth and twentieth centuries, questions were formulated more in terms of climate as a physical system (e.g. Friedmann 1989; see also the systematic approach presented by Arrhenius 1908), and meteorology and oceanography became 'physics of the atmosphere' and 'physics of the ocean'. Climate was no longer primarily considered an issue of the field of geography, but of meteorology and oceanography, and climate science became 'physics of climate' (e.g. Peixoto and Oort 1992).

Since the 1970s the notion that unconstrained emissions of greenhouse gases into the atmosphere generated by human activities will lead to significant changes of climatic conditions—a theory first proposed by Svante Arrhenius (1896)—was supported by evidence of a broad warming and finally embraced by the majority of climate scientists. The series of Assessment Reports by the Intergovernmental Panel of Climate Change (IPCC) are central to and document this change. In the 1990s human-driven climate change became the absolutely dominant topic in climate sciences (Weart 1997, 2010). Climate research became to a large extent driven by concern with human-made climate and its impacts.

Unnoticed by most climate scientists, the developments in the last decades represent a return to the original but transformed *anthropocentric* view of the issue of climate (Stehr and von Storch 2010): In contrast to the perspective of 'climatic determinism', it was no longer the idea that climate *determines* the functioning and fate of societies, but that climate *conditions* human societies (Stehr and von Storch 1997).

3 METHODICAL CHALLENGES OF THE PHYSICS OF CLIMATE

In this section we outline, after a brief retrospect of the success of physics, several concepts in climate science, which are not normally met in conventional physics—and thus represent serious obstacles from a physics point of view. One of the obstacles is the absence of 'the equations' and the need for parameterizations; another is the difficulty to 'predict' and finally the issue of inhomogeneity of data.

The pillars of the success story of physics in the last two centuries are the unbiased observation and description of natural phenomena, the reproducibility of experimental data, and the mathematical description of the empirical results leading to a generalization of the experimental results and the elucidation of the underlying basic laws of nature. Perhaps the most prominent example is the Newtonian classical mechanics which Newton developed on the basis of Kepler's observations and Galileo's gravity experiments. In classical mechanics, the time evolution of a system (like the motion of the earth around the sun) follows Newton's equations. The important thing is that, when the state of the system is known for a certain time (for the earth sun system this is the position and velocity of the earth relative to the sun), then the time evolution of the system can be calculated rigorously and precise predictions can be made. By solving Newton's equations one can predict, for example, the trajectories of rockets, satellites, and space ships, which is the basis for modern space science.

Another example is electrodynamics which was established by Maxwell and based on the experimental and theoretical work by Coulomb, Volt, Ampere, Gauss, and others. Like Newton's equations, the celebrated Maxwell equations describe comprehensively all (classical) electrical and magnetic phenomena, and not only those that they aimed to describe initially. Among others, Maxwell's theory led to the recognition that light is an electrodynamical phenomenon.

Prerequisites of the success of physics were:

- the departure from the anthropocentric view of life that for the first time allowed an unbiased view onto the natural phenomena (like planetary motion);
- a new practice of publication: the protagonists did no longer (like the alchemists) hide their results but made them available to the public, allowing colleagues to reproduce (or falsify) them; and finally

- the norm of checking theoretical hypotheses experimentally. In the case of conflicting theories, an *experimentum crucis* is needed to decide which theory is correct. Perhaps the most important *experimentum crucis* is the Michelson experiment on the velocity of light, which forms the basis for Einstein's theory of relativity.

In climate science, at least two of these requisites do not exist. Climate science has become anthropocentric and *experimenta crucis* are not possible.

When approaching the subject of climate from a physics or mathematical point of view, the first question usually is—what is included, and how to describe it? What are its *equations*?

The climate system has different 'compartments', such as atmosphere, ocean, sea ice, land surface including river networks, glaciers, and ice sheets, but also vegetation and cycles of substances, in particular greenhouse gases (Figure 8.1). An important element of the dynamics is given by fluid dynamics of the atmosphere, ocean and ice, which are described by simplified Navier–Stoker equations. However, due to the unavoidable discrete description of the system, turbulence cannot be described in mathematical accuracy, and the equations need to be 'closed'—the effect of friction, in particular at the boundaries between land, atmosphere, and ocean, need to be '*parameterized*' (e.g. Washington and Parkinson 2005).

Additional equations describing the flow and transformations of energy are needed—part of this may be described by the first law of thermodynamics, the conservation of energy. In these equations we find source and sink terms, which are related to phase changes (condensation, for instance) and the interaction of cloud water and radiation. The sources and sinks often take place at the smallest scales and require additional state variables (such as the size spectrum of cloud droplets). Again, such processes cannot be taken care of explicitly—and need to be 'parameterized'.

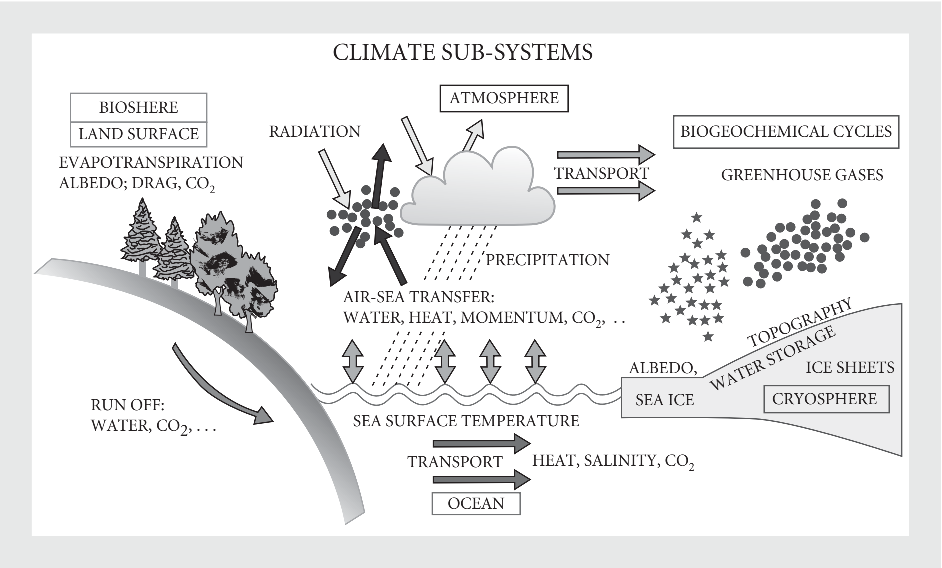

FIGURE 8.1 Schematic sketch of processes and variables in the climate system (reprinted with permission of Klaus Hasselmann)

This issue of parameterization is difficult to understand (Müller and von Storch 2004). The basic idea is that there is a set of 'state variables' $\{\Psi\}$ (among them the temperature field at a certain time *t* at certain *discrete* positions on the globe), which describe the system, and which dynamics is given by a differential *C*equation $d\{\Psi\}/dt = \mathrm{F}(\{\Psi\})$. The function F is nonlinear in Ψ and only approximately known. A rigorous analytical or numerical solution of the equations (as for Newton's equations) is impossible.

To simplify the equations, and make them tractable for a numerical treatment, one splits each of the state variables Ψ into a slowly and a rapidly varying component, $\Psi = \underline{\Psi} + \Psi'$.[1] Ψ represents that part of Ψ, which is well represented with the given spatial resolution (say 100 km), and Ψ' being the unresolved part of smaller spatial scale. The equations are then approximately written as $d\underline{\Psi}/dt = \mathrm{F}(\underline{\Psi}) + \mathrm{G}(\Psi')$. Here, $\mathrm{F}(\underline{\Psi})$ describes the influence of the resolved part Ψ on the future development of $\underline{\Psi}$, whereas $\mathrm{G}(\Psi')$ describes the influence of the non-resolved part, which is of course unknown. A conventional truncation of the equations would lead to $d\underline{\Psi}/dt = \mathrm{F}(\underline{\Psi})$, and the non-resolved part would have no influence. This truncation is only valid in linear systems and thus unacceptable here, where the influence of the small-scale turbulence and the associated friction on the slowly varying state variable $\underline{\Psi}$ cannot be neglected. Another approximation is used, namely $\mathrm{G}(\Psi') = \mathrm{H}(\underline{\Psi})$. The latter is the 'parameterization'. The problem is to specify H.

The idea with the parameterization is that it would carry the information, which is to be expected from the small scales Ψ' when the resolved state is $\underline{\Psi}$. Or more precisely, $\mathrm{G}(\Psi')$ is considered a random variable, which is conditioned by the resolved part $\underline{\Psi}$. Practically, the distribution of $\mathrm{G}(\Psi')$ can be determined empirically—by observing the distribution of G (Ψ') when the large-scale state is $\underline{\Psi}$. The parameterization $\mathrm{H}(\underline{\Psi})$ can then be a random realization of this distribution of $\mathrm{G}(\Psi')$, or the $\underline{\Psi}$-conditional expectation of $\mathrm{G}(\Psi')$.

The usage of parameterizations is normal practice in climate models, and they have turned out to make such models capable of describing the present climate, the ongoing change, and historical climates. It is plausible that the parameterizations are valid 'closures' also in a different climate (after all, in terms of physical (but not societal) magnitudes, any climate change would represent only a minor change), but the final evidence for this belief will be available only after the expected changes have taken place, have been observed and analyzed.

There are two important aspects of parameterizations.

One is a *linguistic* aspect, namely that in the language of climate modelers, parameterizations are named 'physics', a shorthand for 'unresolved physical processes'. For a person uncommon with the culture of climate sciences, this terminology may go with the false connotation that parameterizations would be derived from physical principles. While the functional form of the parameterization $\mathrm{H}(\underline{\Psi})$ may be motivated by a physical plausibility argument, the specific parameters used are either guessed, fitted to campaign or laboratory data,,, or to make the model skilful in reproducing the large-scale climate $\underline{\Psi}$. Thus, the word 'physics' points to semi-empirical 'tricks'.

Another aspect of parameterizations is their *strong dependence on the spatial resolution*. When the model is changed to run on a higher resolution, the parameterizations need to be reformulated or respecified. There is no rule how to do that, when the spatial resolution is increased—which means that the difference equations do not converge towards a pre-specified set of differential equations, or, in other words: there is nothing like a set of differential equations describing the climate system per se, as is the case in most physical disciplines.

To summarize: In climate science, there are not 'the equations' but only useful approximations, which crucially depend on the spatial resolution of the system. This aspect causes many misunderstandings, in particular among mathematicians and physicists who often enough demand to see 'the equations'.

Unlike most physics disciplines climate cannot be associated with *spatial and temporal scales* in a certain limited range—instead climate varies on all spatial scales (on Earth) and extends across several magnitudes of timescales, from short-term events, measured in seconds, via timescales of decades and centuries, to geological timescales of millennia and more years. If we look at the relevant processes in the climate components atmosphere and ocean, we find a continuum of scales, as displayed in Figure 8.2. The implication is that there are hardly independent observations from different locations, and the temporal memory extends across many decades of years.

As a practical rule, the World Meteorological Organization (WMO) mandated a hundred or more years ago that thirty-year time intervals would represent 'normal climatic conditions'; every thirty years new normals are determined. If we accept this somewhat arbitrary number of thirty years, we have to wait about thirty years to get a new realization of the climate system, which is at least somewhat independent of previous states. Thus, tests of hypotheses, derived from historical data, using new data are hardly possible.

Real *experiments*, in the sense of paired configurations, which differ in a limited number of known details, are of course also not possible in the real world (as in any other

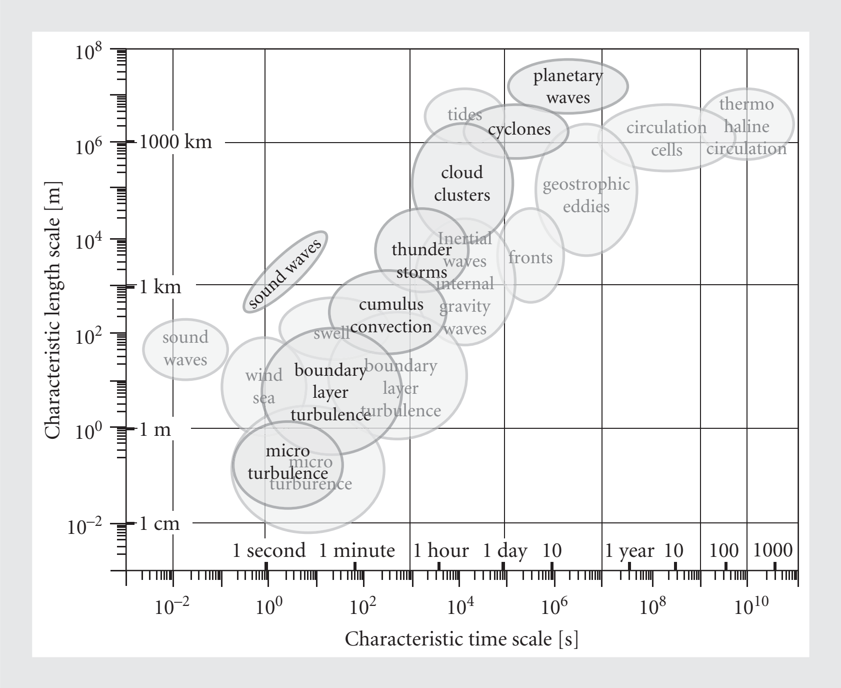

FIGURE 8.2 Spatial and temporal scales of processes in the climate components atmosphere and ocean

geophysical set-up). However, with quasi-realistic models, which serve as a kind of virtual laboratory, it is possible to perform virtual experiments, for instance on the effect of different formulations of clouds, different specifications of physiographic detail, but also on elevated greenhouse gas concentrations in the atmosphere. Independent realizations can be generated; extended long simulations are possible so that the weather noise may be reduced and the looked-after signals, caused by an imposed experimental change in the system, may be more easily isolated. The problem is, of course, that even if the models share indeed many properties with reality, it is unproven if the specific model response is realistic.

Real forecasts are also hardly possible: even if we are able to prepare a successful forecast for the coming ten or thirty years, we cannot claim the 'success' of our prediction scheme, because a single success may also have taken place by coincidence. Determining the skill of a forecast scheme needs many independent trials, as in case of weather forecasting. The long timescale in climate variability does not allow robust estimates of the skill of our methods to explore the future.

Indeed, in recent years sometimes real predictions are tried with dynamic climate models, with lead times of one or a few decades (e.g. Keenlyside 2011). The logic behind such forecasts is that the details of the emissions do not really matter for such a time horizon—as long as they exhibit some increase in the coming decades. A first attempt at forecasting the next ten years (in this case 2000–9) was in the year 2000 published by Allen et al. (2000)—now, ten years later, this prediction can be compared with the actual recent development. The scenario prepared by Hansen et al. in (1988) was retrospectively by Hargreaves (2010) considered a forecast, and compared with the recent development (Figure 8.3). In both cases (Figure 8.3), the future was well predicted. For the coming decades, a reduced warming has been predicted in an experimental forecast effort by Keenlyside et al. (2008).

Most outlooks of possible future climatic developments take the form of conditional predictions—assumed developments of greenhouse gas emissions/concentrations and other factors are used as external drivers in climate models (e.g. von Storch 2007). As such they are scenarios, namely possible future developments, and not predictions, namely most probable developments (cf. the discussion in Bray and von Storch 2009). Such scenarios are often falsely labeled as 'predictions' in the media, and even by some research institutions. They are prepared with *quasi-realistic climate models* (e.g. Müller and von Storch 2004), often abbreviated by GCM (which historically stands for General Circulation Models and not for Global Climate Models)

To summarize: most future outlooks available to the scientific community and presented to the general public are not descriptions of most probable futures (predictions) but plausibly consistent and possible futures (scenarios or projections). In a few cases, real predictions have been prepared for the nearer future, and they have turned out to point into the right direction.

While this is encouraging, such sporadic successes cannot be considered as significant evidence for the general validity of climate models. At the same time, evidence is not available that would positively disqualify such models for being valid tools to study man-made climate change.

The lack of the option to do experiments prevents many uncertainties from being resolved, as for instance the *climate sensitivity* (temperature increase after equilibration when CO_2 concentrations are doubled). Indirect evidence is used for improving the

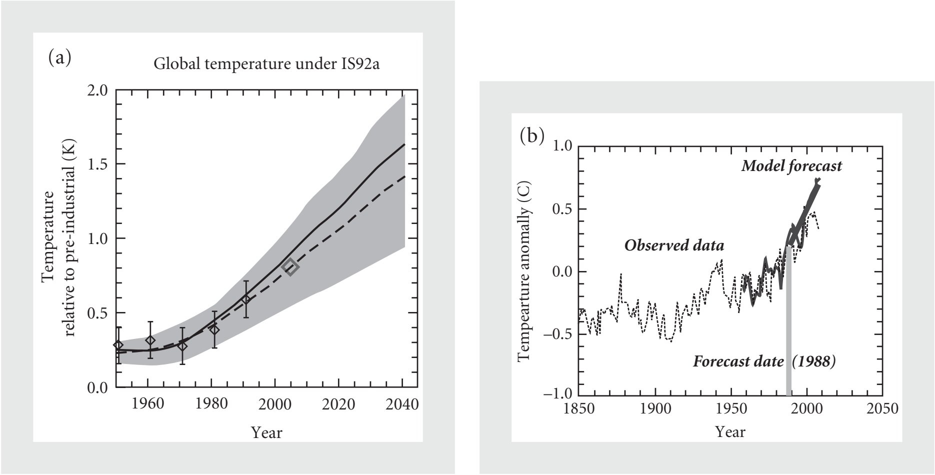

FIGURE **8.3** **Left:** Allen et al.'s (2000) forecast of global temperature made in 1999. Solid line shows original model projection. Dashed line shows prediction after reconciling climate model simulations with the HadCRUT temperature record, using data to August 1996. Grey band shows 5–95% uncertainty interval. Red diamond shows observed decadal mean surface temperature for the period 1 January 2000 to 31 December 2009 referenced to the same baseline. **Right:** Hansen's scenario published in 1988 as a prediction up to 2010 (redrawn after Hargreaves 2010).

estimate of such uncertain quantities, but some uncertainty remains. This leaves a certain range for interpreting the policy implications differently.

Because of the long waiting time for getting a new realization of the climate system, climate science must rely on historical 'instrumental' data, data which have been measured for often quite different purposes, under different conditions, with different instruments and standards. Alternatively, proxy data may be used, for instance data on tree growth or ice accumulation, which may have 'recorded' aspects of the geophysical environment.

The 'instrumental' data usually suffer from 'inhomogeneities' (e.g. Jones 1995; Karl et al. 1993). An example is provided by Lindenberg et al. (2010), who examined statistics of wind speed recorded on islands along the German North Sea coast (Figure 8.4). The diagram shows periods, when the wind speeds co-varied to large extent, whereas at other times, marked by the dashed line, the statistics began to deviate strongly. These deviations are mostly related to the relocation of the instruments for a variety of reasons. Such effects are common in 'raw' data time series, and at least in modern data sets are well documented.

Indeed, it may be a good rule of thumb that almost all time series, extending across several decades of years, suffer from some inhomogeneities—the more easily detectable inhomogeneities are 'abrupt', such as those in Figure 8.4, but the more difficult to detect are continuous changes. An example is the effect of continuous urbanization, which can be separated from the natural variability only within large error bars (Lennartz and Bunde 2009).

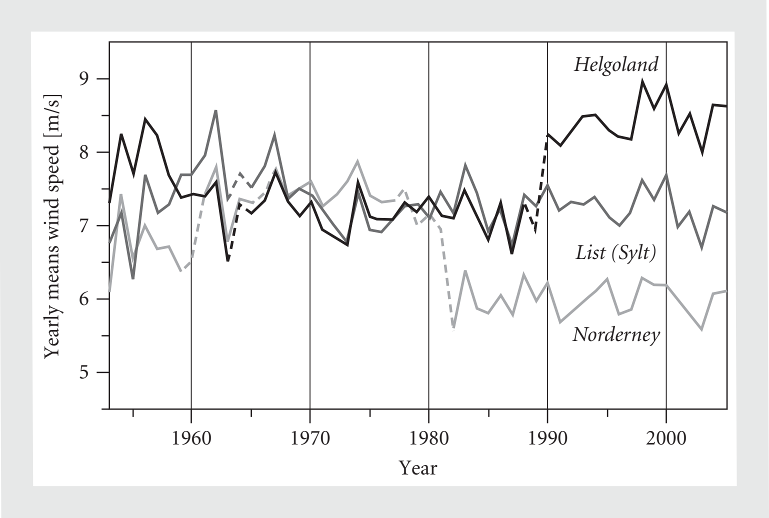

FIGURE **8.4** Yearly means of wind speed measurements from three synoptic island stations. Dashed lines label years with known station relocations (after Lindenberg et al. 2010).

Before using such data in climate analysis, the series have to be 'homogenized' (e.g. Peterson et al. 1998). For scientists and lay people, with insufficient insight into the contingencies of climate data, this significant hurdle is hardly recognized. Therefore, it happens every now and then that publications show surprising results, which in the end display changing data recording practices and not changes in the climate system. A nice example is the conjectured increase of the absolute number of deep cyclones in the last century, which is due to insufficient data knowledge (Schinke 1992). Also, contributors on weblogs often ask for 'raw data,' with the implicit suspicion that somebody may have tampered with the raw data in order to obtain preconceived results. This is in most cases not a wise approach—because of these invisible inhomogeneities (cf. Böhm 2010).

'Proxy'-data have other problems (Briffa 1995). The main problem is that the proxies, for instance growth rings in trees, or annual layers of sedimentary material, record not only some climate parameters, such as summer temperature, but also other influences. The fundamental problem is that only part of the variability in the proxies is related to climate variability, in particular temperature. The proportion of variability, which may be related to climate drivers, differs in time, and the empirically derived transfer functions may show different amplitudes for different timescales. The famous problem of the hockey stick-named temperature reconstruction, which was based mostly on tree rings, had much to do with the non-uniform representation of long-term and short-term variability. An interesting exchange about proxy-methodologies and robust claims making is provided by a series of papers, comment, and replies by Christiansen et al. (2009), Rutherford et al. (2010), and Christiansen et al. (2010).

To summarize: 'Data' entail complex issues in climate research. Historically collected 'instrumental' data often suffer from inhomogeneities, related to changing observational, archival, and analytical practices. Indirect proxy-data provide information about changing physical conditions, but compete with other unknown influences—so that stationarity and timescale dependence of the information content of such data are an issue. More expertise about the process of using instruments and of storing influences in indirect data is required.

Thus, there are a series of obstacles and uncertainties, which are uncommon in conventional physics, which represent special challenges when dealing with climate dynamics and impacts.

4 The Socio-cultural Context

There is another set of factors that makes the science of climate 'different' from other natural science fields—namely that climate research, the issues, results, and individuals—are firmly embedded into socio-historical, socio-cultural, and socio-economic contexts. This is already illustrated by virtue of the fact that most, perhaps almost all, of present climate research activities are related to the issue of anthropogenic climate change and its impact on the natural environment and society.

The main issue in the societal context concerns the statistics of weather (in atmosphere and ocean) and its changes, such as the frequency and intensity of extreme events such as storms, heatwaves, and flooding. Weather statistics are significant data for societies, its infrastructure, and inhabitants because they contain important information about possible impacts (and adaptive measures to deal with them) and options for keeping a check on the drivers (mitigation). Both strategies in response to a changing climate, that is, reducing emissions and reducing vulnerability, are subjects of a wide range of scientific fields including the engineering sciences, hydrology, law, geography, policy sciences, ecology, economy, and social sciences.

Thus, climate research has significant attributes beyond physics. We could now start to discuss the needed contributions from these other fields, but we do not. We instead concentrate more on the functioning of the science–society knowledge interaction.

This interaction of climate research with society in general and with policy making in particular is linked to the joint presence of two factors. One factor that we have just discussed above is the high uncertainty about the 'facts' of climate dynamics, ranging from the climate sensitivity, to regional specification, to the presence of other social drivers and to future options of dealing with emissions and impacts. The other factor concerns the societal response to climatic conditions, how we interpret and deal with climate-related processes. Our ordinary everyday understanding of climate is closely related to our way of life, mediated of course by the way in which the mass media shape climate issues according to media logic (Weingart et al. 2000; Boykoff and Timmons 2007; Carvalho 2010). References to climate and climate change in public communication may be employed for example as a tool to legitimate changes to our way of life, or, in the opposite sense, as a means to defend dominant world-views.

Under these circumstances, but not only because the nature of our understanding of climate is embedded in everyday life, climate science becomes along with other modern scientific fields 'postnormal' (Funtovicz and Ravetz 1985; Bray and von Storch 1999). A broad range of essentially contested terms and explanations enter the public arena and compete for attention, accounts that may also be brought in position to give credence to different world-views and legitimacy to political and economic interests.

There seem to be two major, contending classes of explanations of the climate and climate change (von Storch 2009). One, which we label as 'scientific construct' of human-made climate change, states that processes of human origin are influencing the climate—that human beings are changing the global climate. In almost all localities, at present and in the foreseeable future, the frequency distributions of the temperature continue to shift to higher values; sea level is rising; amounts of rainfall are changing. Some extremes such as heavy rainfall events will change. The driving force behind alterations beyond the range of natural variability is above all the emission of greenhouse gases, in particular carbon dioxide and methane, into the atmosphere, where they interfere with the radiative balance of the Earth system.

The scientific construct is widely supported within the relevant scientific communities, and has been comprehensively formulated particularly thanks to the collective and consensual efforts of the UNO climate council, the IPCC.[2] Of course, there is not a complete consensus on all aspects of the construct in the scientific community, so that speaking of 'the scientific construct' is somewhat of a simplification. What is consensual and enumerated in the previous paragraph is the core of the scientific construct.

A different conception of climate and climate change may be labeled the *social or cultural construct* (cf. Stehr and von Storch 2010). In the context of this concept, climate and weather patterns are also changing, the weather is less reliable than it was before, the seasons less regular, the storms more violent. Weather extremes are taking on catastrophic and previously unknown forms.

What causes these changes in weather patterns? A variety of economic reasons and psychological motives tend to be adduced, for example, sheer human greed and simple stupidity. The mechanism that is at work may be described as follows: Nature is retaliating and striking back. For large segments of the population, at least in central and northern Europe, this mechanism producing climate change is taken for granted. In older times, and even sometimes today, adverse weather patterns were the prompt response of the gods angered by human sins (e.g. Stehr and von Storch 2010).

The cultural construct of climate and changing weather patterns takes many different forms depending on the traditions in a society, its development and dominant aspirations—but what is described above as the everyday concept of climate and weather represents something like a standard core of such statements.

Obviously, the scientific construct in hardly consistent with such cultural constructs.

The position of so-called 'climate sceptics' is not discussed here because there is no consistent body of knowledge of 'sceptic' climate science but merely a collection of various, often highly contested issues that range from detailed matters to much more general assertions, e.g. that greenhouse gases would have no significant impact on climate. The absence of a consistent body of assertions does not imply in principle that the questions raised by 'sceptics' might not in one or the other instance be helpful to constructively move the science of climate forward.

In this postnormal situation where science cannot make concrete statements with high certainty, and in which the evidence of science is of considerable practical significance for formulating policies and decisions, this science is impelled less and less by the pure 'curiosity' that idealistic views glorify as the innermost driving force of science, and increasingly by the usefulness of the possible evidence for just such formulations of decisions and policy (Pielke 2007b). It is no longer being scientific that is of central importance, nor the methodical quality, nor Popper's dictum of falsification, nor Fleck's

(1980) idea of repairing outmoded systems of explanation; instead, it is social and political utility of knowledge claims that carry the day. Not correctness, nor objective falsifiability, occupies the foreground, but rather social acceptance and social utility.

In its postnormal phase, science thus lives on its claims, on its staging in the media, on its affinity and congruity with socio-cultural constructions. These knowledge claims are not only raised by established scientists, but also by other, self-appointed experts, who often are bound to special interests. Representatives of social interests seek out those knowledge claims that best support their own position. One need only recall the *Stern* report (see the critique by Pielke (2007a) or Yohe and Tol (2008)), or the press releases of US Senator Inhofe.

5 CONCLUSIONS

Two major conclusions about the science of climate, and the knowledge about climate may be drawn.

The scientific construct is mostly based on a physical analysis of climate and developed by natural scientists. It describes the left two blocks in Figure 8.5. In the 'linear model' (Beck 2010; Hasselmann 1990) the middle blocks, representing social and cultural dynamics, are not taken into account. Instead, once society has given a metric of determining 'good' and 'less good', it is simply a matter of understanding the 'physical' (including economic) system.

However, the climate scientists are also part of society and not immune to dominant societal conceptions of the nature and the impact of climate and climate change on human conduct, they tend to embed their analysis, especially in efforts to communicate their knowledge to policy makers and society at large in ways which are attentive to the socio-cultural construct of climate and climate change. It is not surprising that in this postnormal situation scientists concerned about the impact of the greenhouse gases, in their desire to

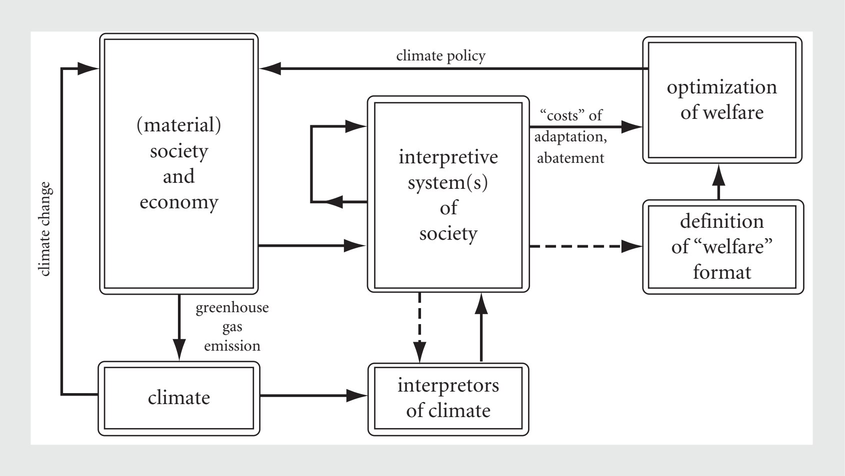

FIGURE 8.5 The perceived climate and society model (after Stehr and von Storch 2010)

save the world, may develop some bias towards an overdramatization. The discussion itself often resembles more a religious than a physics discussion where the non-believers (of the role of the greenhouse gases and their impact) are called 'deniers'.

One therefore is able to surmise that the transfer of the scientific construct into the societal realm goes along with a subtle transformation of the climate knowledge, by blending the scientific construct with the socio-cultural construct (the middle blocks in Figure 8.5). Obviously, in the model described by Figure 8.5, the basic assumption of physics, that there are given quantifiable laws (linear or nonlinear), is no longer valid. Understanding the interaction of climate and society is not only an issue of physical analysis (with laws) but of society/culture analysis (without laws) as well.

Obviously, the situation is not quite that straightforward, it is not easily deconstructed and the interrelations of scientific and everyday construct are difficult to dissemble. To comprehend and disentangle the multiple interactions of science and society in the case of our understanding of climate and climate change is nonetheless a real and worthy scientific and practical challenge. It needs a trans-disciplinary approach, bringing together scientists with a solid background in the physics, and scholars who understand societal and knowledge dynamics (Pielke 2007b).

If this helps to implement a better climate policy, with an efficient constraining of climate change and socio-culturally acceptable measures of mitigation and adaptation, it needs to be developed. Summing up, climate science is and should be much more than just the physical analysis.

NOTES

1. In certain cases this can be done by expanding Ψ into a Fourier-series of trigonometric functions of spherical harmonics. Those with small wavenumbers then make up Ψ, and the rest Ψ'.
2. The support among climate scientists seems indeed very broad, when related to the key assertions just listed (cf. Bray and von Storch 2007). Whether the emergence of errors in Working Group (WG) 2, and possibly WG3, of 4th Assessment Report (AR4) of IPCC, which so far all point towards a dramatization, and after it became known that a key data set (CRU) could no longer be reproduced because of some original data having been 'lost', will have implications for this support within climate science and the general scientific community remains to be seen.

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