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On adaptation – a secondary concern?

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Abstract. The climate problem has many facets. Whether or not humans are capable of significantly changing climate is no longer a scientific question – they are in fact capable of doing so. However, only partly solved is the question what is happening here and now and how far future anthropogenic climate change will or may possibly go. The most important issue, namely how humankind can or should deal with this change, is a political issue, which needs more debate. Adaptation is a key element in this context. These issues are addressed in a non-technical manner here – from a deliberately broad range of perspectives, from both natural and social sciences. This paper is not a review; it is certainly biased in presenting the author's views, analyses and conclusions. According to these views, adaptation is not a secondary concern.

1 Climate

To avoid misunderstandings, we should define what is meant by "climate". Climate is the statistics of weather. The ensemble of all possible weather states, together with their frequency. For practical purposes, this definition is too broad; instead, therefore, representative statistical parameters are commonly considered – such as mean values, dispersion ranges, extreme values, mean summer temperatures and 100-year flood levels. But also correlations in space and time, spectra, EOFs and other statistical descriptors are employed.

When speaking about future climate, two terms – namely "climate predictions (or forecasts)" and "climate projections" are in use. Independently of the terminology, such efforts do not refer to *forecasting the weather* in 20, 50 or 100 years. Instead what is predicted or envisaged is the statistics of the future weather. This is often misunderstood; in popular debates sometimes the argument is voiced that since it is impossible to predict the weather of the next season it would be impossible to assess changes in a few years or even decades of years. All attempts to predict climate would therefore be doomed. However, these attempts are not doomed, – contemporary climate models are indeed capable of envisaging possible future climate. In fact forecasts of future climate may be possible for shorter lead times, but hardly for long lead times, because of our inability to predict with any certainty how future human activities influencing climate will develop. But what we can devise is "scenarios" of possible future climate change.

Before continuing with the main flow of thoughts, we insert a discussion of the two terms "predictions" and "projections" (following [2]). The inconsistent use of these terms is a frequent cause of confusion and misunderstanding.

2 Excursion: Predictions *versus* projections

Two types of calculations are commonly performed to assess the future climate of the coming decades and centuries. The first type is typically called a "*scenario* simulation" [9], the other, a "decadal climate *prediction*" [6]. Both activities involve the use of dynamical climate models that are based on a numerical representation of all relevant processes.

In the calculation of both "decadal forecasts" and "scenario simulations", an *initial state* of the climate system – ocean, atmosphere, cryosphere, etc. – is needed, as well as a scenario of changing forcing conditions, such as the quantity of greenhouse gases in the atmosphere according to patterns of human behavior. The details of the state of the atmosphere at the initial time (the start of the model run) have little if any impact on the modeled climate development after a few weeks of simulated time. The details of the initial soil conditions become insignificant after the simulation of a few years, those of the ocean after many years or even decades. The state of the ice sheets may condition the development of the climate system for still longer times.

In both cases of constructing perspectives for the climatic future, "decadal forecasts" and "scenario simulations", certain prescriptions about the future development of some "external forcings" are needed. Foremost among these are the release of climatically relevant substances into the atmosphere, in particular, greenhouse gases, but also, for instance, volcanic emissions. The forcing related to greenhouse gases is presently derived from given emission scenarios (in particular: IPCC Special Report on Emissions Scenarios (SRES; `http://www.grida.no/climate/ipcc/emission`); future volcanic emissions are usually ignored.

Consequently, the development of the climate system as simulated by a model is determined by the initial state of the climate system and the forcing, with noise being added by the inherently unpredictable (internal) variability of the climate system. During an *initial phase* of this development, the climate system is dominated by the initial state, allowing for the specification of a "most probable" development of the climate system. The length of this phase is unknown, but arguably at most a few decades. As the simulated time increases, the highly uncertain external forcings and internal variability become the dominant factors, severely limiting the simulation of future climate. In this sense, one can perform *short-term predictions* and *long term projections.*

In both cases, any statement about a "probability" hinges on an assessment of the probability of conditioning elements, namely the initial state of the climate system and the forcing scenario. Here a key difference emerges – the initial state is known within given bounds; the forcing scenario however is an educated guess, with no associated probability.[1]

Recently, scientists have made significant progress in exploiting initial state information for determining "decadal forecasts" (cf. [6]). In the case of scenario simulations, however, the critical element "future emissions" cannot be specified with any accuracy as the magnitude of emissions depend upon uncertain factors such as human demographic patterns and energy use patterns, to mention just two – at least not for an extended time. Therefore, these developments are presented as "scenarios" [18], i.e. as possible, plausible, internally consistent, but not necessarily probable, developments. Given that the forcing is not "most probable", but merely "possible", the response of the modeled climate system can only be described as a "possible" and not as the "most probable" future state of the climate.

The IPCC provides the following operational definitions for the climate sciences: "A *projection* is a potential future evolution of a quantity or set of quantities." and "A climate *prediction* or climate forecast is the result of an attempt to produce an estimate of the actual evolution of the climate in the future, for example, at seasonal, inter-annual or long-term time scales." The IPCC document continues "Climate *projections* are distinguished from climate *predictions* in order to emphasize that climate projections depend upon the emission/concentration/radiative forcing scenario used, which are based on assumptions concerning, for example, future socioeconomic and technological developments that may or may not be realized" (see, `http://www.ipcc.ch/pdf/glossary/ar4-wg1.pdf`). In this article, I follow the IPCC definition.

In a survey among climate scientists [2], it was found that the IPCC terminology – projections represent a *possible* development; predictions describe a probable outcome – is not or only loosely adopted by a significant minority of scientists. Approximately 29% of the sample

[1] To make circumstances a bit more complex – the forcing may possibly be predicted for a limited time, for instance as continuing the recent trend for some time, or so, say a decade or two. Then, a probability is associated with the forcing and, consequentially also with the climate projection.

associate *probable* developments with projections and approximately 20% of respondents associate *possible* developments with predictions.

The interest in the deployment of such nomenclature might appear merely a matter of semantics. But both terms, "prediction" and "projections", are common in the conventional scientific discourse as well as in common speech. They are subject to different interpretations and connotations. Thus, the use, if not explicitly specified, has the potential to cause problems not only in the communication of climate science in the broader scientific realm and in the understanding of the public at large, but also for policy decisions, policy design, and policy implementation, and likewise for public perceptions of climate change.

3 The climate problem

The question whether humans can significantly change or influence climate is a problem for the natural sciences. The related question, whether and how strongly recent changes of climate are related to human activity, is equally a problem of natural sciences (cf. [3,5]). Section 4 addresses these issues. In order to avoid misunderstanding, I am declaring already now: I am convinced that humankind can change climate, and I am equally convinced that humankind is presently changing climate.

Another question is how strongly will or may the climate change in the next, say, 100 years. This is dealt with in Section 5. That question is only partially a natural sciences problem, because it depends crucially on the development of the human society in the next 100 years. Specifically, how many radiatively active substances will be released into the atmosphere; which proportion of these substances will be bound in anthropogenic "sinks"? How much trust do we have in the predictive skill of economic scientists? My own trust in this skill is somewhat limited, I have to admit.

The final question is how humankind could deal with climate change, i.e., which responses to the threat, and reality, of climate change may be adequate. Principally there are two options – to live with the change or to avoid it: adaptation and mitigation (cf. [4,10]). Eventually we will pursue a combination of these two measures, but, for some strange reasons, for a long time only the mitigation-option was seriously discussed – at least in Germany. The other option – adaptation – is constructively considered by specialists and practitioners, but in the public discussion this option seems to be considered as morally inferior. In Section 6 I will address this problem: adaptation and mitigation of the expected future climate change.

4 Anthropogenic climate change?

The presently most effective human influence on climate operates via the additional greenhouse effect. The term "greenhouse effect" is certainly a misnomer but it is nevertheless widely used.[2] The basic idea is that Earth will have a temperature that allows the system to emit the same amount of energy that it is receiving from the sun. The latter arrives in the form of short-wave radiation; some of it is reflected, in particular at bright surfaces such as clouds and ice. The loss of energy happens through the emission of thermal radiation, which strongly rises with temperature. The important point is that not all thermal radiation emitted near the surface and in the lower troposphere is lost for Earth (i.e., reaches space); instead certain substances in the troposphere absorb the radiation and re-emit the energy into all directions, among others back to the surface, where this additional energy causes further warming. In the end the system has a temperature that is high enough so that the proportion of the thermal energy "passing by" the "greenhouse substances" into space equals the incoming short-wave energy.

Since the middle of the 19$^{\text{th}}$ century the concentrations of greenhouse gases, in particular carbon dioxide and methane, have been increasing steadily. The accumulation was fastest during the last decades. At the same time we observe an accelerated warming since the 1970s. Is this warming related to the increased levels of greenhouse gas concentrations? This question is far from being simple. Climate, i.e., the statistics of weather, is changing all the time because

[2] For the historical background, refer to [14].

of natural causes – such as the Earth's changing position relative to the sun, the changing energy output of the sun, the variable amount of volcanic material in the atmosphere and, last not least, the internal dynamics of the climate system. Air temperature has significantly changed on a global scale in the past thousand years; the warming during the first third of the 20th century has caused concern about anthropogenic climate change among scientists in the 1930s [7].

The answer is given by the rate of change. How fast can climate change when only natural causes are operating? This rate may be described by a probability distribution. This distribution is not known but must be estimated from the limited evidence provided by the observational data base of the past 150 years and by indirect "proxy data". It is not possible to prove that the estimation is "right"; we can only show that it is consistent with the little knowledge we have. I personally believe that our estimates are approximately correct – but I have to admit that I may be wrong with that assessment.

After we assessed the range of natural variations of climate, we have to decide whether the *recent* changes are within that range or beyond it. If the recent change is beyond that range we conclude that some non-natural causes must be at work. Being non-natural, this cause, or these causes, must be man-made. The technical term is "detection". The next step is to identify the cause(s). This is done by comparing the characteristics of the recent change, which was found to be beyond the range of normal variations in certain aspects, with the changes that our climate models generate as response to prescribed anthropogenic forcing anomalies, in particular the increased levels of greenhouse gas concentrations. If this comparison yields favourable results – the characteristics of recent change are consistent with the changes generated by a climate model when greenhouse gas concentrations are increased – then we "attribute" the part of the recent change which goes beyond the range of natural variations to the greenhouse gases. The same attribution idea is also used to sort out how much of the recent warming is due to changing solar output and other factors.

Commonly accepted knowledge is that no more than one third of the warming of the past hundred years can be explained by increased solar output; the remaining two thirds can be explained only by the effect of elevated greenhouse gas concentrations, i.e., the anthropogenic greenhouse effect.

There is a caveat, though, which I want to repeat: the quality of estimating the magnitude of naturally caused variability is a key issue in this exercise. This magnitude is not known but must be estimated. Accepting its estimated value is a matter of trust. If somebody believes that the estimate is inadequate because of the limited data base, then I can not disprove this assertion. The same is true for my belief that the data base is good enough to allow a reasonable educated guess of this quantity – possible opponents are not able to prove that I am wrong. This controversy has nothing to do with incapable scientists but with the fact that the data available to us are limited. The problem can be solved only by either waiting for a long period of extra time – so that the data base is significantly increased – or by accepting claims such as realism of contemporary climate models.

There is an interesting aspect in the history of science – the human perception that climate is subject to changes seems to be immemorial. My colleague, the sociologist Nico Stehr and I have compiled a list of knowledge claims, which have been used in the past to explain conditions perceived as anomalous [17]. Witches were among the suspected causes of anomalous weather and climate. Another agent was lightning rods, to which anomalous precipitation was ascribed; felling of trees in the high mountains was held to cause floods in the lower parts of Switzerland [11].

This is not just an entertaining historical detail. Instead it has relevance for the present-day perception and discourse. We humans – at least in the western culture – seem to be predisposed to accept "anthropogenic climate change" as an acceptable explanation for uncommon events even if they are natural and simply rare. This may be one of the reasons why the prophets of "climate catastrophes" and disasters are so successful in communicating with the general public – they articulate a primal fear, so to speak an eigen-oscillation of public perception.

The concept of detection and attribution has so far mostly been applied to globally distributed air temperature. In the public discussion, however, often the implicit assumption is made that when a climate change signal is detected in the global mean temperature, which is attributable to increased greenhouse gas concentrations, then all extraordinary meteorological events, like disastrous storms or extensive floods, must also be causally related to this anthropogenic climate change. Sometimes the formulation is more cautious – these events are declared to be "consistent" with anthropogenic climate change. The causal link would not "yet" have been firmly established, but there would be little doubt; only cautious scientists would still hesitate to draw such an "obviously right conclusion". There are even scientists who admit that exaggeration of the threat of climate change would be in order – because without exaggeration the public would not take the threat sufficiently serious [1]. I consider this practice a disservice – for the political decision process and for the culture of discussion and integrity of science. For a scientist such behaviour is dishonourable. Just imagine the consequences if all sciences would pursue this line of "explaining" facts.

If every extreme event is considered a support of the concept of anthropogenic climate change – how would we be able to falsify the hypothesis of anthropogenic climate change, if it would actually be false? Only by the absence of extreme events – which would, on the other hand, be a sure proof of climate change, as extreme events are integral parts of the statistics of weather.

5 Future climate

The Intergovernmental Panel on Climate Change IPCC (SRES, op. cit.) has published a series of plausible but not necessarily probable economic and social global developments, i.e., scenarios. Relevant parameters are the development of the world population, the usage of energy, economic exchange, development of the Third World and many other aspects. These parameters are used to construct scenarios of future emission of radiatively active substances into the atmosphere.

In one of the possible future worlds, the concerns for local social environment is dominant, so that there is a fast economic development and high emission of greenhouse gases. The resulting atmospheric concentration of these gases may well become quadrupled by the end of the 21st century. In another possible future world, emissions are smaller because a more intense international cooperation allows a more favourable spread and use of efficient technology. A third possible world is envisaged as being one of de-materialization, with greatly expanded e-commerce and communication. Explicit measures for climate protection by dedicated agreements to limit emissions are not foreseen in these three scenarios.

These economic and social scenarios lead to scenarios of future emissions, from which one derives forcing functions in climate models, which, in turn, calculate the expected climatic impacts of elevated greenhouse gas concentrations. These climate change scenarios differ from model to model, but many aspects of the different models' scenario simulations are similar. Air temperatures increase and sea level rises. However, scenarios for smaller areas, like Switzerland, for more complex quantities like the distribution of precipitation or the frequency and intensity of wind storms, show a large uncertainty and variability across model configurations and emission scenarios.

Scenario simulations are no forecasts. They are projections of possible futures (see Section 2). They are intended to demonstrate people and decision makers what possibly could happen; what is at stake. Unfortunately this role of scenarios is often misunderstood in the public. Instead the worst-case scenarios are looked at as realistic forecasts of the future, which inevitably will become true if no serious counteraction is taken. Without proper climate protection policy temperature will rise by 5.8 °C until the end of the present century, and the sea level will rise by 88 cm, the public understands. However, these numbers are meant as upper margins of possible developments.

6 Adaptation and mitigation

In a rational world, the state of which is known or can be reliably predicted, allowing optimal planning, the right path to go would be to assess the costs of all possible options of how to deal with the future climate change. One extreme option is not to act at all; then society will develop in an unchecked manner with emission increasing freely. Such a development will be associated with costs, in terms of money, life and morale. Another extreme is to reduce emissions; also this option is associated with costs – mostly in terms of money but also in terms of life and morale. The best decision in this rational "cost-benefit" framework would be that mix of actions that goes with least costs (cf. footnote 3). The problem is that the costs are unknown; everybody determines the costs differently; the knowledge about climate sensitivity, vulnerability and counter measures is not only fragile but also unavoidably loaded with cultural or even ideological presumptions.

But nevertheless – we have to take a decision. How much effort should be directed toward reducing emissions, and how much toward adaptation? The public debate in Germany and Scandinavia favours the "protection of climate", i.e., mitigation, reduction of emissions. Al Gore declared "we have to be careful not to siphon off political will from job one, prevention, and dissipate it with adaptation".[3] This decision has the advantage that it seems to be morally superior – everybody feels the obligation to protect the Creation.[4] Another advantage is that specific questions about the implications on regional and local scales can be qualified as secondary. The response strategy is obvious: reduction of emissions as much as possible. However: anthropogenic climate change is ongoing now; it can not be stopped; all what we can do is to limit climate change. The foreseeable future will hardly see any reduction of global emissions – but merely reductions of global emission growth.[5] If we continue with business-as-usual and if no deus-ex-machina technological fit surprisingly emerges, we may well end up with a tripling or maybe even quadrupling of greenhouse gas concentrations in the atmosphere at the end of the current century. Such levels will have severe implications. Making serious attempts to reduce emissions, we may be able to limit the increase in the greenhouse gas concentrations to a doubling of pre-industrial levels. [6] "Doubling" is to be considered an achievement; a successful limitation. But also a doubling will have serious implications.

Therefore we have to consider adaptation to climate change, not instead of, but parallel to mitigation of climate change. The goal is to limit the accumulation of greenhouse gases to "only" a doubling (or any other achievable significant reduction) and to prepare societies and ecosystems to adapt to unavoidable future changes.

Can we adapt? I believe we can, as long as the changes are not too radical. For instance a melting of the West-Antarctic Ice Shelf would cause very serious challenges, which could hardly be mastered. However, such an event is not probable in the foreseeable future. But what about warming and heat waves at mid latitudes, the spread of malaria, increased frequency of severe flooding, Bangladesh – all these topical and typical examples of imminent climate disasters of the future? Can we adapt to these threats? I believe that we can. But this requires that we begin to better adapt to these threats *now*, considering also the unavoidable lead times. An added aspect is that climate is dangerous already today, even if, probably, less so than 50 years from now due to the further human interference with climate. The disastrous 1953 storm surge in the Netherlands, is a good example of this sort of "normal" threats – and it is just 50 years

[3] In New York Times `http://www.time.com/time/specials/2007/personoftheyear/article/0,28804, 1690753_1695417_1695747,00.html;` also: "We really have to focus on prevention," Al Gore said on Tuesday during a question-and-answer session at Columbia University in New York City. International Herald Tribune: `http://www.iht.com/articles/ap/2007/02/23/america/NA-FEA-GEN-Climate-Change-An-Update.php`

[4] A clearly religious dimension is associated by some prominent climate scientists, such as the previous chairman of working group 1 of the IPSS, Sir John Houghton, about whom was written by Frances Welch, 10.9.95 in an article "me and my God" in *Sunday Telegraph*, 10.9.95: An expert on global warming and Chairman of the Royal Commission of Environmental Pollution, Houghton warns that God may induce man to mend his ways with a disaster. "God tries to coax and woo, but he also uses disasters." Und: "If we want a good environmental policy in the future we'll have to have a disaster."

[5] Any regional reduction will very likely be offset by even larger increases in other regions, for the foreseeable future.

[6] Here, "doubling" is meant as a vague concept describing orders of magnitude. It is not related to the "2 degree goal" of the EU, which is merely a number suitable for convenient political communication, c.f., [16].

ago. The more recent events of various river floodings in Germany (Elbe, Odra and Rhine), the disaster brought out by tropical storms at New Orleans in 2005 and to Myanmar's coastal regions in 2008 are also in the range of normal, but rare hazards. In theses cases, society turned out to be badly prepared.

A closer inspection of these climate impacts reveals that in all cases climate plays a certain role – but that social, technological and economic factors play an equally if not more important role. Take two examples, heat waves and malaria.

The heat wave of 1995 in Chicago was analysed in detail [8]. It caused many deaths. The people died because of heat stress, but they would not have died if the city would have been properly prepared for the situation. The people who perished were not a random sample of the population; they were old, poor and lonely people; they did not dare to leave their insufficiently ventilated apartments because of real or perceived dangers of being assaulted by criminals. In the 1950s people would sleep during heat waves in the parks of the city, but in the 1990s people were afraid of visiting the parks after dark. Other cities are prepared for such a situation; endangered individuals are contacted when extreme temperatures are expected, and brought into air-conditioned shopping malls. It was the failure of social mechanisms, the absence of adequate adaptation which made the extreme temperatures lethal. "Climate" may even serve in this situation as a perfect scapegoat for the city administration – the killer was the heat wave. "We did not make the heat; we were not responsible". Or, as Berthold Brecht's Johanna is saying: "The calamity comes like the rain; made by nobody".

Malaria (e.g., [13]) – lay people widely believe that the spatial distribution of malaria a determined by the air temperature. But malaria was common in Europe up into the first half of the 20th century. In wetlands of The Netherlands and England, life expectancy was only half of that in other regions. That people in these regions no longer suffer from malaria is not to be explained by lower temperatures – but by modern hygienical and medical standards and better land usage. The return of malaria in some parts of the previous Soviet Union is also not related to a warming of climate but to the troubled medical systems in those parts of the world. Malaria is a problem of poor people. Thus, not only the heat wave case but also the malaria case demonstrates that the allegedly climatic problems were primarily social problems. Malaria is associated with poverty, and it deserves our full attention now and not only in some remote future, when climate change will have caused additional problems.

Neither malaria nor heat stress is adequately dealt with by reduced usage of fossil fuels and reduced emissions of greenhouse gases; the proper response is to make people and societies less vulnerable to these dangers. This should be done now. If it turns out, as we expect, that these dangers are getting more serious as a consequence of climate change, then the adaptive measures will be even more useful. There is no doubt hat we can reduce vulnerability today. Instead, many people concentrate on reducing enhanced vulnerabilities in some future, and forget about the basic fact that climate has always been und remains to be dangerous, even without anthropogenic interference.

We will have to live with anthropogenic climate change, because it will not be possible to avoid it completely – at least unless surprise technical fixes become available. And we are able to do so, if we begin well in time to prepare ourselves for what may come in the future. Humans, societies and ecosystems have proven to be flexible in the past; they will master this challenge also. But it is prudent to reduce the climatic change as much as we can without compromising other important goals of sustainable and other essential conditions. In short, reduction as much as possible, but only if affordable in terms of social costs.

Before concluding this essay, I want to briefly discuss an observation: The emphasis on "protection of climate" and the wrong causality of emissions and weather extremes is not a possibly pedagogically acceptable simplification but, on the contrary, a detrimental disinformation. It causes people to falsely believe that normal weather extremes are really related to climate change, and that such extreme would no more happen as soon as a successful climate policy is installed. The vulnerability against weather extremes is enhanced because of the false perception that we are facing a revengeful environment which is striking back against the perpetrator – instead of the view that extremes of this sort are "normal" and need preparation on our side even if these events are rare. It is prudent not to rebuild one's house in the flood plains. The

Dutch 1953 storm surges caused a major re-definition of the national coastal defence concept; after the big flooding in the Elbe catchment in 2002, people rebuilt their houses and demanded financial compensation by the state: "I do not need to be prepared; this disaster was caused by society – thus they have to pay for the damage und make sure to prevent it in future."

Climate science [12] must return to its old mission of advising and not directing the public. The primacy of politics to decide which topics are to be dealt with which priority and with which action, needs to remain with the democratically legitimized representatives. They, and not the scientists, have the responsibility and task to decide how to deal not only with climate change but also with all the other pressing problems.

Climate is dangerous already now. It will, presumably, become more dangerous in future. The unlimited growth of emissions must be limited, but at the same time the vulnerability of societies, economies and ecosystems needs to be reduced (cf. [15]). Adaptation is not a secondary issue.

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