

ANTHROPOGENIC CLIMATE CHANGE: A REASON FOR CONCERN SINCE THE 18TH CENTURY AND EARLIER

BY
HANS VON STORCH¹ AND NICO STEHR²

¹H. von Storch, Institute for Coastal Research, GKSS Research Center Germany, Germany

²Am Seemooser Horn 20, Friedrichshafen, Germany

Von Storch, H. and Stehr, N., 2006: Anthropogenic climate change : a reason for concern since the 18th century and earlier. Geogr. Ann., 88 A (2): 107–113.

ABSTRACT. During the last 20 years the concept of anthropogenic climate change has left academic circles and become a major public concern. Some people consider 'global warming' as the major environmental threat to the planet. Even though mostly considered a novel threat, a look into history tells us that claims of humans deliberately or unintentionally changing climate is a frequent phenomenon in Western culture. Climate change, due to natural and anthropogenic causes, has often been discussed since classical times. Environmental change including climate change was seen by some as a biblical mandate, to 'complete the Creation'. In line with this view, the prospect of climate change was considered as a promising challenge in more modern times. Only since the middle of the 20th century, has anthropogenic climate change become a menacing prospect. The concept of anthropogenic climate change seems to be deeply embedded in popular thinking, at least in Europe, which resurfaces every now and then after scientific discoveries. Also, extreme weather phenomena have in the past often been explained by adverse human interference.

A list of claims of anthropogenic climate modifications is presented; the remarkable similarity of the anthropogenic climate change debate in the second half of the 19th century is compared to the present situation. Of course, the present threat seems much more real than any of the historical predecessors, which turned out to be overestimated.

Climate change and the history of ideas

In 1890, the geographer Eduard Brückner (1890; Stehr and von Storch 2000) wrote in his dissertation about anthropogenic climate change and natural climate variability, about winner and loser states, and about parliamentarian committees dealing with the implications of climate change:

'Very old and wide-spread is the opinion that forests have an important impact on rainfall. ... If forests enhance the amount and frequency of precipitation simply by being there, deforestation as part of agricultural expansion everywhere, must necessarily result in less rainfall and more frequent droughts.... It is not surprising that under such circumstances the issue of a link between forests and climate has ... been addressed by governments. Lately, the Italian government has been paying special attention to reforestation in Italy and its expected improvement of the climate. ... It must be prevented that periods of heavy rainfall alternate with droughts. ... In the United States deforestation plays an important role as well and is seen as the cause for a reduction in rainfall. ... American Association for Advancement of Science demands decisive steps to extend woodland in order to counteract the increasing drought. ... some serious concerns. The congress for agriculture and forestry discussed the problem in detail; when the Prussian house of representatives ordered a special commission to examine a proposed law pertaining to the preservation and implementation of forests for safeguarding, it pointed out that the steady decrease in the water levels of Prussian rivers was one of the most serious consequences of deforestation only to be rectified by reforestation programs. It is worth mentioning that ... the same concerns were raised in Russia as well and governmental circles reconsidered the issue of deforestation'.

Most contemporary climatologists take it for granted that the concept of anthropogenic climate change is of relatively recent origin. (By 'climate change' we do not mean changes of the local climate by the expansion of cities, clearing of single

forests and other local modifications of land use. Instead we are referring to anthropogenic changes of regional or global scale). It is surprising for them, and most of the public, that 'anthropogenic climate change' is by no means novel. As we can see from Brückner's discussion, concerns over extensive transformations of the earth's climate have been expressed in Europe since the 18th century Enlightenment And Earlier.

Glacken (1967) offers a comprehensive analysis of Western thought about nature and culture from classical times to the end of the 18th century. The concept of human agency in changing not only climate but the environment as a whole has prevailed in Europe since classical times. Theophrastus, from the 4th century BC, may be seen as a pioneer, who stood at the beginning of a long history of speculation concerning climatic change and its impact on humans – climatic determinism (Stehr and von Storch 1999). In the 18th century, the Scottish philosopher and historian David Hume (1711–1776) speculated that the recent warming could be caused by human deforestation, which would allow the rays of the sun to reach the surface of the Earth. A contemporary, H. Williamson, published evidence for his view that the northern colonies of America had become more temperate in the aftermath of colonization (Williamson 1771). Others claimed that human action would render climate more irregular and less predictable (Glacken 1967).

People were aware of climate variations, which were evident in, for instance, the freezing of rivers, the success of harvests and the damage done by storms to dykes (e.g. Lamb 1982; de Kraker 1999). They speculated about the reasons for these changes, which had a significant impact on daily life. An obvious explanation was heavenly intervention, with God steering climate partly as a response to people's behaviour. In Medieval times, for instance, it was proposed that climatic anomalies, or extreme events, were a punishment for parishes that were too tolerant of witches (Behringer 1988). On the other hand, man was considered to have been placed on Earth to complete the Creation (Glacken 1967). Environmental change was a task given to mankind by God himself. An alternative view was that Earth as organic, and would therefore age with time: '...array of occurrences seriously regarded as evidence of decay; almost any natural phenomenon was suitable: air pollution, storminess, weather changes, earthquakes, volcanoes, and so forth' (Glacken 1967).

History of anthropogenic climate change

In the following paragraphs we present elements of a 'history of anthropogenic climate changes'. Most of the cases were not real; as a matter of fact, none of them proved to be associated with significant impacts related to the suggested dynamical link. But all cases were associated with the perception of significant discontinuities; in most instances the apprehended change was seen as a threat; only rarely were they welcomed as an improvement.

1. Religious interpretations of climate anomalies, such as the prolonged wet period in England in the early 14th century, explained the adverse climatic conditions as the divine response to people's lifestyle (Stehr and von Storch 1995). In Medieval times, for instance, it was proposed that climatic anomalies, or extreme events, were a punishment for parishes that were too tolerant of witches. Witches were believed to be able to directly cause adverse weather (Behringer 1988). There was a sophisticated system of rogation in response to droughts in Spain (Barriendos-Vallvé and Martín-Vide 1998).

2. Our oldest case documented by contemporary scientific writing refers to the climate of the North American colonies (Williamson 1771). The physician Williamson analysed the changes of climate, and related them to clearing of the landscape by settlers. This is a case in which human action was perceived as having a beneficial impact on climate. More cases during Medieval times, related to colonization by monks, are described by Glacken (1967).

3. In many parts of Europe, the summer of 1816 was unusually wet, presumably because of the eruption of the volcano Tambora. However, people ascribed the adverse conditions to the new practice of using lightning conductors. The case is documented in two articles published in the newspaper *Neue Zürcher Zeitung* (21 June and 9 July 1816). The authorities called the concerns unsubstantiated and issued grave warnings concerning violent and illegal acts against the conductors. Interestingly, it is mentioned that some years earlier in Germany, people blamed the conductors for being responsible for a drought.

4. In the 19th century scientists in Europe and in North America were confronted with the concept

that the climate would be constant on historical time scales; however, scientists found significant differences between mean precipitation and temperature when averaged over different multi-year periods (e.g. Brückner 1890). Also, scientists claimed that the water levels of rivers would fall continuously. This led to questioning of the assumption of constant climatic conditions – in modern terms, interdecadal natural variability – and, alternatively, to the hypothesis that the observed changes are caused by human activities, mainly deforestation or reforestation. It seems that the majority adopted the concept of man-made causes over the natural variability hypothesis (Brückner 1890; Stehr *et al.* 1996).

5. The developing science of forestry (e.g. Grove 1975) informed people that the severe floods in Switzerland in the middle of the 19th century would be related to logging of forests in the high mountains (Pfister and Brändli 1999). The flooding was falsely perceived as novel so that a novel cause was sought; as a consequence the Swiss Forest Law was instituted, an early progressive environmental law, which was most useful to limit an unsustainable practice, but was based on false scientific arguments.

6. There are reports that both the extensive gun-fire during the First World War and the initiation of short-wave trans-Atlantic radio communication were blamed for wet summers in the 1910s and '20s (Kempton *et al.* 1995: Hinzpeter pers. comm.).

7. In the first part of the 20th century a remarkable warming took place in many parts of the world. In 1933, this warming was documented, and the uneasy question 'Is the climate changing?' was put forward in *Monthly Weather Review* (Kincer 1933). Some years later, Callendar (1938) related the warming to human emissions of carbon dioxide into the atmosphere, a mechanism described some 40 years earlier by Arrhenius (1896). Interestingly, Arrhenius (1903) himself stated that anthropogenic emissions of CO₂ would cause a significant climate change only after several hundred years. Flohn (1941) also brought this line of reasoning into the scientific debate. In the 1940s global mean temperatures began to fall, which eventually led to claims that Earth was heading towards a new Ice Age.

8. After the Second World War scientists noticed a

cooling and some speculated whether this cooling was the first indication of a new Ice Age, possibly brought on by human actions, mostly emissions of dust and industrial pollution. It was speculated that human pollution would increase by a factor of as much as eight which could increase the opacity of the atmosphere within 100 years by 400%. This in turn would significantly reduce incoming sunlight causing the global mean temperature to sink by 3.5K. Such a cooling would almost certainly be enough to force Earth into a new Ice Age (Rasool and Schneider 1971). The prospect was illustrated with the words: 'Between 1880 and 1950 Earth's climate was the warmest it has been in five thousand years. ... It was a time of optimism. ... The optimism has shriveled in the first chill of the cooling. Since the 1940s winters have become subtly longer, rains less dependable, storms more frequent throughout the world.' (Ponte 1976: 89).

9. After the Second World War, the new practice of exploding nuclear devices in the atmosphere caused widespread concern about the climatic implications of these experiments. According to Kempton's analysis, even nowadays many lay-people are concerned about this link (Kempton *et al.* 1995).

10. In Russia, plans for re-routing Siberian rivers southward have been discussed since the beginning of the 20th century. The plans visualize benefits in supplying semi-arid regions with water, and an improved regional climate. A by-product was thought to be an ice-free Arctic Ocean because of the reduced freshwater input from the rivers. This would shorten the winters and extend the growing season; the increase of evaporation from the open water would transform the Arctic climate into a maritime climate with moderate temperatures and busy harbours along the Soviet Union's north coast (Ponte 1976: 136). Such plans were formally adopted in 1976 at the 25th Assembly of the Soviet Communist Party. Scientists from the West as well as from the Soviet Union opposed these plans and warned that the formation of an ice-free Arctic could significantly affect the global ocean circulation and thus global climate. Eventually, the plans were abandoned although more careful analyses indicated that the probability of melting the Arctic sea ice associated with a re-routing of the rivers was overestimated (e.g. Lemke 1987).

11. The concept of engineering or manipulating the

climate system became popular in the first half of the 20th century. Re-routing Siberian rivers was one such scheme; another was put forward by the New York engineer Riker, who in 1912 suggested changing the Gulf Stream with the purpose of improving the climate not only of North America but also of the Arctic and Europe. Riker's idea was summarized by Ponte (1976: 138).

'The Gulf Stream travels up along the American coast without any problem, but when it turns east to cross the Atlantic Ocean it collides with the Icy Labrador Current coming down from the Arctic. This collision in relatively shallow water weakens the Gulf Stream ... But this would change ... if a simple jetty 200 miles long could be built from Cape Race on Newfoundland to a point just beyond the underwater Grand Banks. The jetty would keep the two currents apart ... Off the tip of Greenland ... the more powerful Gulf Stream would divide. Half would throw increased warmth against Northern Europe, and half would thrust into the Arctic... The benefits of this would be enormous. Fog would disappear, all ice in the Arctic would melt. The melting of the Arctic would improve the world climate in two ways... Europe and North America would be freed of chilling storms and icy ocean currents... And without the North Polar ice, the surviving ice pack at the South Pole would become the heaviest part of our planet. Centrifugal force would then tip the Earth ... With the Northern hemisphere tipped more towards the sun, Europe and North America could expect warmer climate.'

It is interesting to note that Riker thought of warming as an improvement of climate. The same view is put forward by H. Lamb (1982). Also, the idea of modifying ocean currents was later pursued by scientists from the USA, USSR and other nations. In most cases, these schemes revolved around the building of a dam, which would, for instance, block the flow through the Bering Strait. Ponte (1976) offered a sketch displaying a large variety of such plans.

12. Similar to the idea of climate engineering is the military use of climate modifications. The idea of changing the course of the Gulf Stream had been put forward in the 18th century by Benjamin Franklin, who envisaged a northward diversion of the Gulf Stream as a powerful weapon against the British Empire (Ponte 1976: 137). A perceived attack

using climate as a weapon is a purported Soviet plan in the 1950s to build a 'jetty 50 miles or more long out from near the eastern tip of Siberia. The jetty would contain several atomic powered pumping stations that would push cold Arctic waters down through the Bering Strait. This would ... inject increasing amounts of icy waters into the ocean current that flows down the west coast of Canada and the United States. The result would be colder, more stormy weather throughout North America and enormous losses to the American economy in agriculture, work days and storm damage.' (Ponte 1976: 169–170). Concern about the development of climate weapons led to a series of diplomatic discussions. During a summit meeting in 1974 the United States and the Soviet Union issued a Joint Draft Treaty: 'Each State Party to this Convention undertakes not to engage in military or other hostile use of environmental modification techniques having widespread, long-lasting or severe effects as the means of destruction, damage or injury ... the term "environmental modification techniques" refers to any technique for changing – through the deliberate manipulation of natural processes – the dynamics, composition of the Earth, including its biota, lithosphere, hydrosphere and atmosphere ... so as to cause such effects as ... changes in weather pattern, ... in climate patterns, or in ocean currents.' (Ponte 1976: 259–263). During that period – and even recently – the idea of militarily controlling the battlefield was publicly discussed and requested.

13. In the 1960s and '70s aircraft industries in the USA, Europe and Soviet Union designed supersonic civil air planes. These plans provoked substantial criticism. Scientists argued that the exhaust from such planes would damage the ozone layer in the stratosphere and the climate in general. In the USA the plans were stopped, but in Europe the Concorde was built and in the Soviet Union the TU 144. Of course, numerous military supersonic aircraft are nowadays cruising the lower stratosphere. For many years, discussion about the impact of air traffic on the climate ceased. But in the early 1990s the topic re-entered the public debate, this time regarding high-flying conventional jet liners. The focus of concern is the effect of contrails and exhaust gases on the radiative balance of Earth. Scientists (e.g. Sausen and Schumann 1998) regard present effects from these sources as minor compared to other effects. However, some argue that with present projections of future passenger numbers and technology the effect could be significant.

14. A popular, but for natural scientists somewhat surprising, mechanism links space traffic to a deteriorating global climate. In Kempton *et al.*'s (1995) interviews with lay-people, this mechanism is mentioned several times: 43% of the respondents in Kempton's survey considered the statement 'there may be a link between the changes in the weather and all the rockets they have fired into outer space' plausible.

15. The ongoing deforestation of tropical forests is of great concern to many people, who are afraid not only of reduction in the variety of species but also of changes in global climate (Kempton *et al.* 1995; Dunlap *et al.* 1993). Model calculations indicate that these land use modifications cause significant local and regional changes whereas in most model calculations global effects are marginal. Interestingly, similar results were obtained for the climatic implications of the transformation of the North American wilderness into agricultural land (Cope-land *et al.* 1996).

16. Anthropogenic aerosols are considered powerful agents for changing the global climate. One scenario deals with the emission of aerosols mainly from burning forests and fossil fuels. A dramatic version is that of 'nuclear winter' in which it was assumed that the explosion of a multitude of nuclear bombs in a future war would create a high-flying veil of soot particles which would effectively shut off solar radiation and cause a collapse of the biosphere (Cotton and Pielke 1992). Support came from a number of computer simulations. The ignition of the Kuwait oil wells in the aftermath of the 1991 Gulf War led some scientists to expect a minor nuclear winter, particularly with respect to the Indian monsoon. It turned out that the effect was severe locally but insignificant on the larger scale (e.g. Cahalan 1992).

17. A new line of concern, especially in Europe, refers to the stability of the Gulf Stream in the Atlantic Ocean. Ocean models exhibit a markedly non-linear behaviour of the Atlantic circulation with two stable states, one with an active Gulf Stream and another with a weakened northward transport moderating the European climate. Both states are stable within a certain range of conditions, but when the system is brought to the margins of these ranges, it can switch abruptly to the other state (Marotzke 1990). Palaeoclimatic reconstructions using evidence from ice cores and other indirect

sources support the existence of such stable states and frequent rapid changes from one state to another. In the global warming debate the risk of a 'collapse' of the Gulf Stream is put forward. While the globe is becoming warmer, Europe and northeast America would experience colder conditions.

Social and cultural processes

Which social and cultural processes make the concept of anthropogenic climate change not merely an episodic but an almost permanent issue that challenges scientists and alarms non-expert? Under present circumstances, such social processes include the need for scientists to frame their problems so that they fit the area of their expertise, the readiness of members of the scientific community to engage in public agenda setting, and the desire of scientists to have a presence in the media (Bray and von Storch 1999b). The fact that concern about climate has prevailed not only in recent decades but for many centuries indicates that humans depend fundamentally on the reliability of climate, and that sometimes this reliability is perceived as being endangered. It is interesting to note that climate change mostly takes an apocalyptic form, with the appearance of extremes, more severe droughts and floods, and more violent storms (Glacken 1967; Ponte 1976). We suggest that anthropogenic climate change is of permanent, often dormant concern for people in the West. It can be revived at any time by weather extremes, which are, at least in modern times, not taken as rare but normal events, but as scripture on the wall spelling imminent home-made disaster. In former times, attention ceased after a while when conditions returned to normal.

Because of the open, complex character of the climate system (Oreskes *et al.* 1994), the long time scales involved and homogeneity problems of the observational record, knowledge about the climate system will always suffer from significant uncertainty. On the other hand, as we have seen, climate change is an important topic, arousing public interest and concern. Thus climate change research is bound to be post-normal science (Funtowicz and Ravetz 1985), characterized by high uncertainty and high stakes (Bray and von Storch 1999a), with policy and science influencing each other, and public, antagonistic debates among not only scientists but activists and other non-experts as well.

In most of the instances we have listed, the actual

threat of anthropogenic climate change was either absent or an extravagant claim made by the scientific community. Of course, in the present case of 'global warming', we do not know at this time if it is a real threat or if the warnings are exaggerated as in earlier cases. The fact that the **Intergovernmental Panel on Climate Change** (IPCC; e.g. Houghton *et al.* 2001) is examining the scientific evidence with great care and in 1995 made its famous statement that 'the balance of evidence suggests that there is a discernible human influence on global climate.' and that other official bodies such as the Enquete Commission of the Deutscher Bundestag (1988) voiced grave concerns, may be considered as support for the reality of the envisioned threat.

However, 100 years ago, parliaments and governments in Europe (e.g. Prussia, Italy and Russia) also established distinguished committees that were asked to deal with the reality of anthropogenic climate change related to deforestation (Brückner 1890). And about 200 years ago the British Parliament was discussing the climatic implications of human modifications in British tropical colonies (Grove 1975).

The notion that we are really facing large-scale man-made climate at this time is supported by a large body of scientific analysis, of which possibly the so-called 'detection and attribution'-studies are the most important (IDAG 2005). 'Detection' means that the record of observational evidence is examined, if the most recent changes are beyond the range of natural variability (Hasselmann 1993). For temperature, at least, this condition is fulfilled, so that it is concluded that non-natural factors are at work. In the next 'attribution' step (Hasselmann 1998), climate model simulations are screened for that mix of responses to various anthropogenic factors which best describes the most recent trend: this is a mix of elevated atmospheric greenhouse gas and aerosol concentrations. Thus, there is good empirical evidence that anthropogenic climate change is taking place now (see also Houghton *et al.* 2001).

Conclusions and outlook

So far, climate research has almost exclusively been concerned with the natural-science dimension, i.e. with the dynamics of the climate system, its sensitivity to external disturbances and perspectives for the foreseeable future. The present article points out that there is also a cultural dimension of

'climate'. Only a few researchers are actively engaged in studying the social and cultural processes of speaking about climate, of the formation and usage of lay knowledge, of the formation and social functioning of mental images, icons and popular explanations of climate and its interaction with people. We are in need of social and cultural sciences to map, understand and, as far as possible, predict the social and cultural construction of climate. These issues are not only of academic interest, but have a significant bearing on the ongoing public debate about anthropogenic climate change (von Storch and Stehr 2000). This type of knowledge is urgently needed to guide policy-makers and the public in developing and adopting rational policies for dealing with the very real prospect of significant future climate change (Sarewitz and Pielke 2000)

Acknowledgements

We thank Paul Malone for improving the manuscript.

Hans von Storch, Institute for Coastal Research GKSS Research Center, Max Planck-Strasse 1, 21502 Geesthacht, Germany

Niko Stehr, Am Seemooser Horn 20, Friedrichshafen, Bodensee 88045, Germany
E-mail: nico.stehr@t-online.de

References

- Arrhenius, S.A.*, 1896: On the influence of carbonic acid in the air upon the temperature of the ground. *Philosophical Magazine and Journal of Science*, 41: 237–276.
- Arrhenius, S.A.*, 1903: Lehrbuch der kosmischen Physik. Volume Two. Leipzig: S. Hirzel, 1026 p.
- Barriendos-Vallevé, M. and Martín-Vide, J.* 1998: Secular climatic oscillations as indicated by catastrophic floods in the Spanish Mediterranean coast area (14th–19th centuries). *Climatic Change*, 38: 473–491.
- Behringer, W.*, 1988: Hexenverfolgungen in Bayern. R. Oldenbourg Verlag, München. 546 p.
- Bray, D. and von Storch, H.* 1999a: Climate Science. An empirical example of postnormal science. *Bulletin of the American Meteorological Society*, 80: 439–456.
- Bray, D. and von Storch, H.* 1999b: Climate Science and the transfer of knowledge to public and political realms. In: von Storch, H. and Flöser, G. (eds): Anthropogenic Climate Change. Springer Verlag, Berlin. 287–328.
- Brückner, E.*, 1890: Klimaschwankungen seit 1700 nebst Bemerkungen über die Klimaschwankungen der Diluvialzeit. Geographische Abhandlungen herausgegeben von Prof. Dr. Albrecht Penck in Wien. E.D. Hölzel. Wien and Olmütz, 325 p.

- Cahalan, R., 1992: Kuwait oil fires as seen by Landsat. *Journal of Geophysical Research*, 97: 14,565–14,571
- Callendar, G.S., 1938: The artificial production of carbon dioxide and its influence on temperature. *Quarterly Journal of the Royal Meteorological Society*, 64: 223–239.
- Copeland, J.H., Pielke, R.A. and Kittel, T.G.F., 1996: Potential climatic impacts of vegetation change: a regional modeling study. *Journal of Geophysical Research*, 101(D3): 7409–7418.
- Cotton, W.R. and Pielke, R.A. 1992: Human Impacts on Weather and Climate. ASTeR Press. Ft. Collins. 288 p.
- De Kraker, A.M.J., 1999: A method to assess the impact of high tides, storms and storm surges as vital elements in climate history. The case of stormy weather and dikes in the Northern part of Flanders, 1488–1609. *Climatic Change*, 43: 287–302.
- Deutscher Bundestag, 1988: Schutz der Erdatmosphäre: Eine internationale Herausforderung. Deutscher Bundestag, Referat Öffentlichkeitsarbeit. Bonn. 582 p.
- Dunlap, R.E., Gallup, G.H. Jr., and Gallup, A.M. 1993: Health of the Planet: A George H. Gallup Memorial Survey. Gallup International Institute. Princeton, New Jersey, USA.
- Fleming, J.R., 1998: Historical Perspectives on Climate Change. Oxford University Press. Oxford. 194 p.
- Flohn, H., 1941: Die Tätigkeit des Menschen als Klimafaktor. *Zeitschrift für Erdkunde*, 9: 13–22.
- Funtowicz, S.O. and Ravetz, J.R., 1985: Three types of risk assessment: a methodological analysis. In: Whipple, C. and Covello, V.T. (eds): Risk Analysis in the Private Sector. Plenum. New York. 217–231.
- Glacken, C.J., 1967: Traces on the Rhodian Shore. University of California Press. 763 p.
- Grove, R.H., 1975: Green Imperialism. Expansion, Tropical Islands Edens and the Origins of Environmentalism 1600 – 1860. Cambridge University Press. 540 p.
- Hasselmann, K., 1993: Optimal fingerprints for the detection of time dependent climate change. *Journal of Climate*, 6: 1957–1971.
- Hasselmann, K., 1998: Conventional and Bayesian approach to climate change detection and attribution. *Quarterly Journal of the Royal Meteorological Society*, 124: 2541–2565.
- Houghton, J.T., Ding, Y., Griggs, D.J., Noguer, M. van der Linden, P.J., Dai, X., Maskell, K. and Johnson, C.A., 2001: Climate Change 2001: The Scientific Basis. Cambridge University Press. 881 p.
- IDAG, 2005: Detecting and attributing external influences on the climate system. A review of recent advances. *Journal of Climate*, 18: 1291–1314.
- Kempton, W., Boster, S.J and Hartley, J.A. 1995: Environmental values in American Culture. MIT Press. Cambridge MA and London. 320 p.
- Kincer, J.B., 1933: Is our Climate Changing? A Study of long-term temperature trends. *Monthly Weather Review*, 61: 251–259.
- Lamb, H.H., 1982: Climate, History and the Modern World. Methuen. London. 387 p.
- Lenke, P., 1987: A coupled one-dimensional sea ice-ocean model. *Journal of Geophysical Research*, 92(C12): 13,164–13,172
- Marotzke, J., 1990: Instabilities and multiple equilibria of the thermohaline circulation. PhD thesis Universität Kiel. 194 p.
- Oreskes, N., Shrader-Frechette, K. and Beltz, K., 1994: Verification, validation, and confirmation of numerical models in earth sciences. *Science*, 263: 641–646.
- Pfister, C., and Brändli, D. 1999: Rodungen im Gebirge – Überschwemmungen im Vorland: Ein Deutungsmuster macht Karriere. In: Sieferle, R.P. and Greunigener, H. (eds): Natur-Bilder. Wahrnehmungen von Natur und Umwelt in der Geschichte Campus Verlag. Frankfurt/ New York. 9–18.
- Ponte, L., 1976: The Cooling. Prentice-Hall. Englewood Cliffs, NY. 306 p.
- Rasool, S. I. and Schneider, S. H., 1971: Atmospheric carbon dioxide and aerosols: Effects of large increases on global climate. *Science*, 173: 138–141.
- Sarewitz, D., and Pielke, R. jr. 2000: Breaking the global-warming gridlock. *The Atlantic Monthly*, July 200: 55–64.
- Sausen, R. and Schumann, U., 1998: Estimates of the climate response to aircraft emission scenarios. Institut für Physik der Atmosphäre 95. DLR. 26 p
- Stehr, N. and von Storch, H. 1995: The social construct of climate and climate change. *Climate Research*, 5: 99–105.
- Stehr, N., and von Storch, H. 1999: An anatomy of climate determinism. In: Kaupen-Haas, H. (ed.): Wissenschaftlicher Rassismus – Analysen einer Kontinuität in den Human- und Naturwissenschaften. Campus Verlag. Frankfurt and New York. 451 p.
- Stehr, N., and von Storch, H. (eds) 2000: Eduard Brückner – The Sources and Consequences of Climate Change and Climate Variability in Historical Times. Kluwer, Dordrecht. 338 p.
- Stehr, N., von Storch, H. and Flügel, M., 1996: The 19th century discussion of climate variability and climate change: analogies for present day debate? *World Research Review*, 7: 589–604
- von Storch, H., and Stehr, N. 2000: Climate change in perspective. Our concerns about global warming have an age-old resonance. *Nature*, 405: 615.
- Williamson, H., 1770: An attempt to account for the change of climate, which has been observed in the Middle Colonies in North America. *Transactions of the American Philosophical Society*, 1: 272

Manuscript received August 2005, revised and accepted September 2005