A Consideration on Dangerous Level of Global Warming

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Abstract

To prevent global warming, as stated in Article 2 of the United Nations Framework Convention on Climate Change (UNFCCC), stabilization of greenhouse gas concentrations in the atmosphere and limitation of temperature increases to certain levels are required. Identification of the critical level of temperature increase (i.e., the level where danger occurs) in order to allow ecosystems to adapt, food to be produced and economies to develop is a fundamental issue, as is the implementation of reduction measures to ensure that temperatures do not exceed this level. However, to identify dangerous levels of temperature increase, we need to examine the factors that influence the target temperature so as to ensure it does not exceed the threshold, i.e., the border between danger and safety. For example, the European Union (EU) has accumulated scientific knowledge and decided that 550 ppm should be the stabilization concentration of greenhouse gases, and a temperature rise of 2°C or less should be the long-range target for preventing global warming. Examination has started of the framework stated in the Kyoto Protocol for beyond 2013. To set up a specific long-range target, scientific knowledge of related factors such as stabilization concentrations, level of temperature increase, and effect threshold plays an important role. On the basis of past impact studies, this paper considers levels of temperature rise and thresholds for the impacts caused by global warming.

Key words: global warming, impact threshold, stabilization, UNFCCC, 2°C temperature rise

1. Introduction

To prevent global warming, as indicated by Article 2 of the UNFCCC, stabilization of greenhouse gas concentrations in the atmosphere to below certain levels is required. Namely, the ultimate objective of preventing global warming is to stabilize greenhouse gas concentrations, so that they will not interfere artificially with the climate system, and to achieve a stabilized level within a time frame in which a ecosystems can adapt naturally and in which both developed and developing countries can progress in a sustainable manner without threatening food production.

The problem here is the level of effect at which these ecosystems can adapt naturally without succumbing to these above-mentioned threats. In considering the "danger level" – because exceeding it leads to risk – we need to define who is at danger and how we will comprehensively treat this danger, because from the point of view of effects the danger level is closely related to the amount of temperature increase, greenhouse gas concentrations in the atmosphere and volumes of greenhouse gas emissions.

In regard to the danger level, starting with the Intergovernmental Panel on Climate Change (IPCC), there have been a succession of studies based on scientific knowledge in relation to Article 2 of the UNFCCC. In 1994, the IPCC held a workshop in Fortaleza, Brazil, to discuss global warming and stabilization concentrations. The results of the workshop were summarized and incorporated in the Second and Third Assessment Reports, but the IPCC has not yet identified the danger level. The reason the IPCC has not identified the level is that the line of thought has been that scientists should simply utilize their scientific knowledge to analyze dangerous levels, and the judgements should be left to the policymakers.

On the other hand, European countries such as the Netherlands and Germany understand stabilization concentrations as a long-range objective for preventing global warming. They have furthered analyses of the relationship between absolute temperature rise and the rate of rise, and their effects, and the amount of reduction of greenhouse gas emissions at which atmospheric temperatures are stable. On the basis of early accumulated scientific knowledge, the EU determined a value of 550 ppm as the stabilization concentration for a 2°C temperature rise and set this value as the long-range objective of global warming measures such as energy policies.

The Kyoto Protocol came into effect on 16 February 2005. Various sorts of provisions securing the effectiveness of the Kyoto Protocol at COP11/COPMOP1 were laid down in December 2005. Finally, to fulfill the international treaty to reduce greenhouse gas emissions by 5% within the first commitment period, progress is being made on real preventive countermeasures. Achieving the objective of the Kyoto Protocol is most important. However, discussions of the post-Kyoto Protocol now that it has started, including the availability of goal-setting after 2013 (i.e., Beyond Kyoto or the Beyond 2013 issue), have been initiated. In these discussions, the stabilization concentration in the atmosphere, as defined in Article 2 of the UNFCCC, and the time taken to achieve this concentration, are the most important items to think about.

This paper summarizes the background scientific knowledge on stabilization concentrations and looks into stabilization with a temperature rise of less than 2°C, as proposed by the EU, as the current long-range objective of global warming prevention.

2. Dangerous Levels for Ecosystems and Human Communities

2.1 Five concerns caused by global warming

In a serious global warming situation, the effects grow as the temperature rises. Their scopes and magnitudes vary, depending on the targeted effects and the area. For example, it is reported that a water temperature rise of 1°C generates coral reef bleaching, leading to complete extinction of the coral. Figure 1 is a general outline of the effects in the five fields or concerns cited in the Third Assessment Report summarized by the IPCC (2001) as follows. (1) Vulnerable systems such as ecosystems, are influenced by a small temperature rise (1°C or less). (2) Under extreme meteorological phenomena (extreme events), even in the early stage of global warming extreme weather/climates influence the environment. (3) In regard to the distribution of negative effects, although an area with a temperature rise of around 2°C to 3°C will receive some gains (*e.g.*, crop cultivation is possible in northern cold areas), when the temperature increases by this amount or more the adverse effects will stand out. Because developing countries consisting of small island states or located in coastal areas are affected enormously by even a small sea level rise, a rise of 2°C should be considered a high relative risk. (4) If we view the global economy as integrating the effects in individual fields, then the adverse effects stand out, whereas favorable effects can be found in the early stages of global warming in the case of a 2°C to 3°C rise. If a further temperature rise is found, then (5) the risk of occurrence of catastrophic phenomena may not be ignored. For example, although the possibility of occurrence of extensive phenomena in the 21st century, such as the cessation of oceanic general circulation, has been estimated to be small (IPCC, 2001), according to recent research, fast global warming increases the probability and risk of this occurring (Rapley, 2006). These days we are focusing on such phenomena with low probabilities of occurrence and enormous effects.

In the Third Assessment Report, in considering positive or negative effects of global warming in addition to those of Fig. 1, the IPCC interpreted a 2°C to 3°C rise as the threshold from the viewpoint of the social economy. Subsequently, researchers proceeded to study the effects of global warming and found that global warming and its effects (such as melting of sea

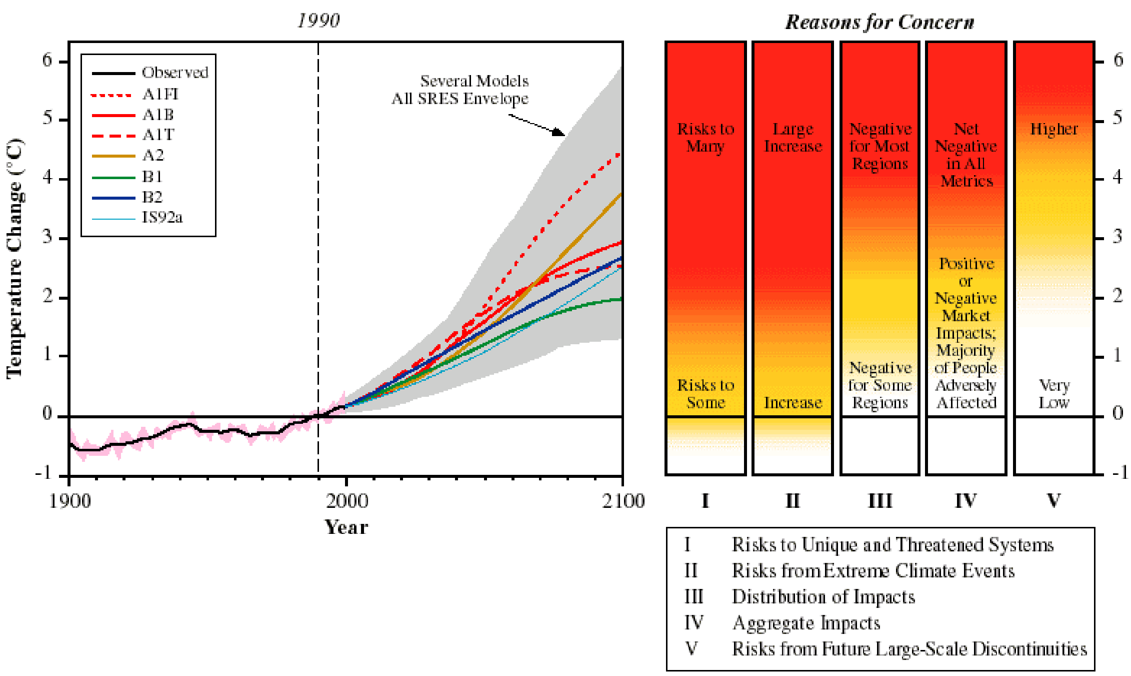

Fig. 1 Five reasons for concern due to global warming. (IPCC, 2001)

ice in the Arctic or of mountain glaciers in the Himalayas) were more widespread than scientists traditionally thought (Schellnfuber *et al.*, 2006). Furthermore, the damage caused by the heatwave that hit Europe in 2003 and by Hurricane Katrina, which struck Louisiana in 2005, awakened people's interest in global warming and extreme climate events and provoked a need to review the danger level.

2.2 Effect threshold (critical limit of global warming effects)

Figure 2 indicates that the concentrations of greenhouse gases discharged as a result of human activity increase in the atmosphere, giving rise to climatic changes such as temperature rises and changes in rainfall, as well as influencing, and having relevance to, each field and region.

What range of levels is not dangerous to ecosystems and human beings, social economy systems, etc.? We call this point the "threshold" or "limit value" of global warming effects. The level that is not dangerous varies around the threshold or limit value, depending on the target (exposure unit), whether it is an ecosystem or a social economy system, and whether or not it is decided that all the Earth's systems will be catastrophically affected. Schneider classifies the type of threshold or limit value into two categories, namely, Type 1 and Type 2 (Schneider & Lane, 2006).

(1) Type 1 threshold (critical limit associated with socioeconomic effects)

This value is defined as that which brings damage unacceptable to policymakers when it exceeds a certain point. The threshold takes the function form of a line or smooth variation.

For example, the admissible uppermost limit for a population exposed to risks such as food shortages, water shortages, health deterioration caused by climate change, and a decreased extent of admissible biodiversity is included. Such examples are found in the range of (2), (3) and (4) in Fig. 1. The function form examples for temperature rise and effect threshold are considered to be (a) and (b) in Fig. 3. In (a), the effects occur in accordance with temperature rise. This means that exceeding a certain constant temperature (the danger threshold) actualizes the effects. Another function form actualizes positive effects when the temperature rise is small, whereas a continuous temperature rise actualizes adverse effects and the threshold of effects is reached later. For example, people may be able to develop agriculture in places where they could not have done it before because the temperatures were too low, or ships can run since the sea ice has melted.

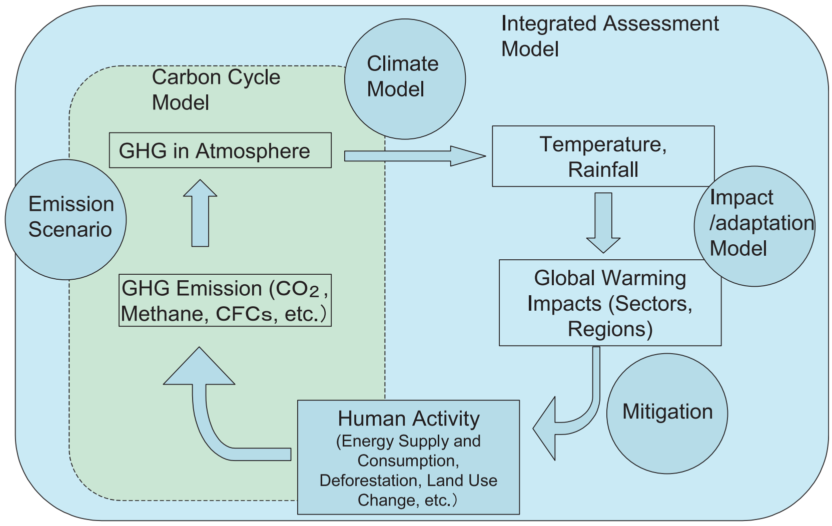

Fig. 2 Emission scenario—climate prediction—impacts/adaptation assessment.

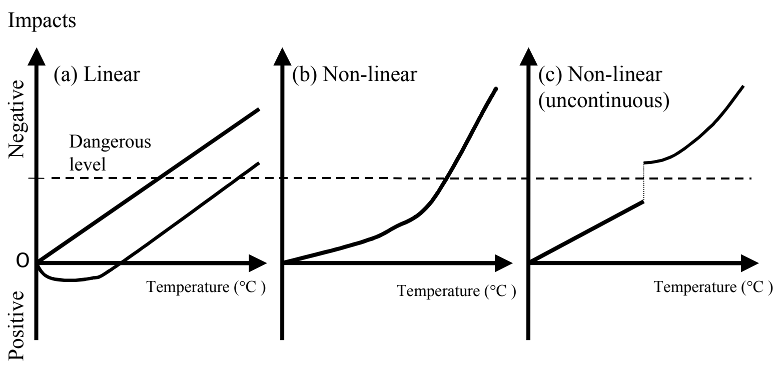

Fig. 3 Temperature increase and impact threshold.

(2) Type 2 threshold (threshold associated with catastrophic effects)

To keep the major processes of the climate system stable and express the geophysical and biological limit values, this value should not be exceeded. The function form of this threshold shows changes that are nonlinear or that "jump."

For example, it includes the cessation of thermohaline circulation, which destabilizes the climate system, melting the West Antarctic Ice Sheet and the Greenland Ice Sheet and thus causing irreversible sea level rise. Melting of the permafrost (permanently frozen ground) causes rapid emission of greenhouse gases. Such examples are found in the range of (1), part of (2) and (5) in Fig. 1. Figure 3 (c) is an example of the effect threshold in a catastrophe.

2.3 Dangerous level of global warming and approach to the effect threshold

On the basis of the results of effect studies, we examine the threshold that actualizes the danger level and the effects of global warming. Ecosystems (coastal wetlands, animal species and onshore, forest and marine ecosystems), agriculture, water resources, human health, energy and economics are included. There have been studies summarizing global warming in these fields in terms of the danger level (See Table 1).

Smith & Hitz (2003) and Hitz & Smith *et al.* (2004) reviewed studies of the effects of temperature rise according to various fields, thereby proposing that the effect threshold for global warming should be 3°C to 4°C. Parry *et al.* (2001) studied four main fields – food, flooding, water shortages and malaria – showing the relationships between temperature rise and populations at risk. Although the relationships between temperature rise and its effects differ according to the targeted field, for a population at risk of water shortages, when a temperature rise of 1.5°C to 2°C is reached, the risk to the population rapidly increases. Their assumption was that the temperature range is a rough indicator of the threshold. Hare (2003) devised a system for comparing effects and risks by expressing them by dark and light colorings ("Burning Embers" diagram.) Schneider and Lane (2006) indicated the thresholds for various fields in a table (Table 2). On the basis of recent case studies, they showed effects ranging from those on ecosystems to large-scale phenomena.

After reviewing studies of the effects on ecosystems, Leemans and Vliet (2004) pointed out that 2°C, which the EU set up as the long-range objective to prevent global warming, could not ensure the safety of ecosystems. They indicated that it should be reduced to 1.5°C, and they further insisted that the rate of reduction should be 0.05°C/ decade. Warren (2006) organized the effects reported at the scientific symposium entitled "Avoiding Dangerous Climate Change," held in the UK in February 2005, as well as other effects. He insisted that a rise of 1°C would influence the ecosystems of the oceans and Arctic; a rise of 1.5°C would cause melting of the Greenland Ice Sheet; and a rise of 2°C would cause a reduction in crop production, increase in populations with water shortages and food shortages. It would produce refugees in coastal areas because of the rise in sea level, increase the risk of malaria, collapse Arctic ecosystems and cause the extinction of ecosystems around the world. Furthermore, a temperature of 3°C

Table 1 Studies of the threshold of global warming effects.

Researcher	Threshold of effect*	Remarks
Third assessment report of IPCC (2001)	Around the range of a few degree Celsius, the effects are divided into adverse and positive ones. For example, a temperature rise of a few degree Celsius or less increases crop production in some mid-latitude areas. On the other hand, an average yearly temperature rise of a few degree Celsius or more may decrease crop production in other areas in the mid-latitudes.	"A few degree Celsius" is understood to be 2° to 3°C.
Smith & Hitz (2003), Hitz & Smith (2004)	After a review of the studies of effects according to various fields, these authors comprehensively summarized the function between temperature rise and its effects. In regard to the effects on the social economy, a temperature rise of 3°C to 4°C became the threshold.	
Parry *et al*. (2001)	Focusing on four main fields—food, floods, water shortages and malaria—these authors showed the relationship between temperature rise and influence on populations. In a population at risk of water shortages, when a temperature rise of 1.5°C to 2°C is reached the risk to the population increases rapidly.	
Hare (2003)	Various effects and risks can be compared by expressing them as dark and light colors ("Burning Embers" diagram).	
Schneider & Lane (2006)	Thresholds of various fields are shown in a table. From the effects on ecological systems, large-scale and catastrophic phenomena are organized as study cases.	
Leemans & Eickhout (2004)	After reviewing studies on the effects on ecosystems, these authors pointed out that the 2°C rise that was set up by the EU as a long-range objective could not ensure safety and should be reduced to 1.5°C; they further insisted that the rate of temperature increase should be 0.05°C/10 years.	
Warren (2006)	This author reviewed case studies of the degree of temperature rise caused by global warming and its effects, and analyzed tabulated data on scientific knowledge of the amount of temperature rise.	

* Beginning in 1990, temperatures have risen. The amount of temperature rise since preindustrial years: 0.6°C is required to be reduced.

would cause a rapid increase in water shortages, food shortages, dengue and malaria, and most ecosystems would not be able to adapt. A temperature rise of 5°C would cause thermohaline circulation to collapse and the West Antarctic Ice Sheet to melt. Additionally, the number of extreme climatic events was predicted to increase.

(1) Ecosystems

At the scientific symposium held in the UK, participants summarized the effects on ecological systems, including the latest scientific knowledge. According to the report, for example, in coral reefs, a water temperature rise of 1°C would cause bleaching of 82% of corals, and 2°C would cause 97% bleaching. Thus, even a water temperature rise of 1°C would cause serious damage. A rise of 1°C would cause a decrease up to 47% in the distribution of animal species; 2°C would cause a 5% to 66% decrease, and 3°C would cause a 7% to 74% decrease. Another study pointed out that the danger level of decrease in distribution range is 20% to 30%.

(2) Food production

The Third Assessment Report by the IPCC stated, in regard to the effects on food production, that crop production is adequately ensured even if we consider population increase. However, once the demand and supply of food are unbalanced, developing countries of the tropical and subtropical zones will not be able to conduct agricultural production. Furthermore, since they will not be able to purchase crops from the market, it is predicted that they will suffer from famine or starvation. A temperature rise of 2°C to 3°C is predicted to have a positive effect in enabling agricultural production in some areas. In the case of food production, a temperature rise of 2°C to 3°C globally can be considered the danger level. In developing countries, since this value may have serious effects, the rise should be limited to 1°C to 2°C.

(3) Water resources

If we take scientific knowledge into consideration with respect to water resources and their relationship with average air temperatures globally, a temperature rise of 1°C to 1.5°C would influence water resources and water supply and demand. A rise of 2°C or more would expand the effects on the water supply and demand and on water quality.

(4) Effects on health

The population that could be affected by diseases such as malaria and dengue fever was calculated from the projected expansion in the potential area of malaria caused by global warming. The lower the temperature rise, the lower the effects, since the size of the affected population increases with global temperature. In regard to direct effects such as heat waves and heat stress in the mid-latitudes, certain temperatures are said to exist at which mortality increases, decreases, or increases further. A threshold of effects on health can be derived from the relationship between the effects of heat waves, air temperature, and mortality. For example, in a heat wave in Japan, when the daily maximum temperature exceeds 30°C, the number of people transported to hospitals with heat stress starts to increase, and when the temperature exceeds 35°C the numbers of patients rapidly increases. Because people gradually adapt themselves to heat and can mitigate its effects by using air-conditioners and other methods of cooling, even if the extreme heat continues, it is difficult to derive a danger level for effects on health in terms of global temperature rise only.

(5) Economic impacts

Economic impacts are calculated mostly by lost amounts of GDP. However, temperature rises work entirely differently from economic losses (IPCC, 2001). It is thought that an economic loss of 3% to 5% seriously influences the social economy. However, the capacity of developed countries is different from that of developing countries, of course, and there are still only a small number of case studies on the economic effects of global warming, because the effects on ecological systems and damage evaluations are difficult to comprehend.

(6) Large-scale phenomena

In regard to the threshold for large-scale and irreversible phenomena, such as the cessation of general oceanic circulation and melting of the West Antarctic Ice Sheet and the Greenland Ice Sheet, there are few studies relating to global warming because the level of uncertainty is still high. However, together with the

Table 2 Dangerous anthropogenic interference. (Scheider & Lane, 2006)

Vulnerability	Gobal mean limit	References
Widespread bleaching of coral reefs	>1°C	Smith *et al*. (2001), O'Neill and Oppenheimer (2002)
Broad ecosystem impacts with limited adaptive capacity (many examples)	1°C~2°C	Leemans & Eickhout (2004), Hare (2003), Smith *et al*. (2001)
Large increase of persons-at-risk of water shortages in vulnerable regions	450~650 ppm	Parry *et al*. (2001)
Increasingly adverse impacts, most economic sectors	>3°C~4°C	Hitz & Smith (2004)
Shutdown of thermohaline circulation	3°C (100 years), 700 ppm CO_2	O'Neil & Oppenheimer (2002), Keller *et al*. (2004)
Disintegration of West Antarctic Ice Sheet	2°C, 450 ppm CO_2 2°C~4°C, <550 ppm CO_2	O'Neil & Oppenheimer (2002) Oppenheimer and Alley (2004, 2005)
Disintegration of Greenland Ice Sheet	1°C	Hansen (2004)

growing interest in global warming, people are making progress in climate modeling studies and are coming to comprehend such phenomena by examination of past (geologic) climates. Traditional studies point to 3°C/100 years for cessation of oceanic general circulation and 2°C for melting of the West Antarctic and Greenland Ice Sheets (Table 2).

(7) Scientific knowledge of the rate of temperature change

A need has been pointed out to consider the rate of rise in temperature in addition to the absolute rise in temperature caused by global warming (WBGU, 2003). Table 3 lists studies that consider both the absolute temperature value and the rate of rise.

The combination of a temperature rise of 1°C to 2°C and a rate of rise of 0.1°C to 0.2°C/ decade has been reported. Leemans and Vliet (2004) pointed out that, to retain the soundness of ecological systems, the rate should be suppressed to 0.05°C/ decade. Because of the lack of scientific data comparing degrees of temperature rise, the continuous high temperatures since the 1980s, and the considerably excessive rate of rise indicated in Table 3, the rate of temperature change has not been treated as a long-range objective, unlike the absolute temperature.

(8) Summary of data on danger level

Scientific data on global-scale effects were collected according to field. On the basis of present data on the amount of temperature rise, the effects and thresholds can be summarized as follows. These values are rough indications at present. In the future, additional data will be available for conducting quantitative evaluations of a more definite dangerous level.

a) Effects on ecosystems
   1°C to 1.5°C: Effects on ecosystems
   To 1°C: Effects on coral reefs
b) Effects on social economic systems
   2°C to 3°C: Food production
   To 2°C: Effects on food production in developing countries
   To 2°C: Effects on water resources
c) Effects on global systems
   1°C to 2°C: Ice sheets of Antarctica and Greenland start to melt
   3°C or more: Possibility of oceanic general circulation cessation, etc.

The temperature rises shown here use values from after the industrial revolution. According to the IPCC report, since calculations of future climate are currently made using climate models based on emission scenarios starting in 1990 and studies of effects using the above calculations, there are many possible amounts of temperature rise. However, the temperature had already increased by 0.6°C during the 100 years of the 20th century. If the starting point is determined to be before the industrial revolution, then we have to note that the value deducted by 0.6°C from the amount of temperature rise is available with which to compare. We also have to note that in the mid-latitude area, including Japan, the degree of temperature rise has been greater than the global average.

3. Conclusion

The Conferences of the Parties to the UNFCCC – COP11 and COP/MOP1 – were held in Montreal, Canada from 28 November to 9 December 2005 after the the Kyoto Protocol went into effect. During the series of conferences, complete rules for administering the Kyoto Protocol were set out, and developed countries came to work on achieving the assigned reduction target. Discussion on the framework after the first committment period (2008 to 2012) has not been initiated. Although agreements to examine the next framework were not reached, it was agreed to start a constructive dialogue on activities for long-range cooperation by all the countries. To examine the next framework, we will need to quantify a long-range objective that effectively prevents global warming, namely, the extent to which greenhouse gases should be reduced before 2050 or 2100.

At the same time, dangerous levels of temperature rise and effect thresholds are being discussed. The UNFCCC has defined the stabilization of greenhouse gas concentrations in the atmosphere. Although time lags between the emission of greenhouse gases and temperature rise have existed from the outset, these two events are tied closely to each other. Since the concept of how to value the levels of danger of temperature rise is included in this problem, we can say that this is not only a scientific issue but also a policy issue. However, for global warming, the proposal of scientific data based on scientific knowledge, including professional "risk comprehension," will be more important. The author hopes that studies on the effects of global warming in Japan will yield the fundamental information we need to set up stabilized concentrations and long-range objectives.

Table 3 Scientific data on dangerous level (temperature rise and rate of rise).

Researcher	Concrete value (Amount of temperature rise and rate of rise)	Document
Vellinga *et al.*	Temperature rise of 2°C and rate of rise 0.2°C/decade causes collapse of society and increases risk of global system instability.	Vellinga & Swart (1991)
Matsuoka *et al.*	Temperature rise of 1°C to 2°C and rate of rise of 0.1°C to 0.2°C/decade.	Matsuoka *et al.* (1996)
WBGU	Temperature rise of 2°C and rate of rise of 0.2°C/decade.	WBGU (1995, 1997, 2003)
Leemans *et al.*	Temperature rise of 1.5°C and rate of rise of 0.05°C/decade.	Leemans & Vliet (2004)

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