Swiss Re

Opportunities and risks of climate change

Risk Perception

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Preface

In 1994, when Swiss Re published "Global warming: element of risk", its first brochure on the climate issue, there was still a great deal of uncertainty as to whether global climate could be influenced noticeably by human intervention. Today, global warming is a fact. The climate has changed: visibly, tangibly, measurably. An additional increase in average global temperatures is not only possible, but very probable, while human intervention in the natural climatic system plays an important, if not decisive role.

The question, then, is no longer whether the climate is changing, but how the occurring climate change will affect our existence and what conclusions can be drawn from it. Nor can discussion be confined to the obvious dangers of extreme meteorological phenomena. Climate change does not merely imply a possible increase in extreme levels, such as higher wind speeds or an increase in precipitation. Instead, it means above all a change in average, "normal" weather. This sounds harmless, and there are some who will obviously benefit from it. However, such climatic anomalies can threaten the very existence of others, and the aggregate of the consequences can assume the proportions of natural catastrophes, as the "summer of the century" in 1995 demonstrated in England and Wales.

Two strategies must be united to avoid the consequences of such climate changes. The first is climate protection which is necessary to prevent global warming from accelerating to such degree that humans are no longer able to adjust themselves in time. Second, we must refrain from merely allowing our technical and socio-economic systems to react to climatic developments, but rather adapt them to anticipate changeable climates.

The individual can make only a limited contribution to climate policy, since this is primarily a task for governments and the community of states. Adaptations to changes in the weather, on the other hand, must be made by the affected individuals themselves.

And who is affected by climate changes? In a word, everyone. Climate change – a change in the average weather conditions – may have both positive and negative effects in individual cases, but it can never be without consequences. Since the weather influences all areas of life, climate changes affect each and every one of us.

Thus, the decisive issue again is not whether we have to adapt, but to what, when and how. This publication examines possible answers. It shows how the forecasts of climate research can be broken down into practical measures, and thus aims to make the concrete effects of climate changes visible.

If climate change accelerates and we fail to adapt to it in time, we will suffer losses in terms of safety and prosperity. This is the risk. If we learn to manage our natural resources responsibly, and adapt readily and intelligently to the constant change in the decisive factors, we can maintain and even enhance safety and prosperity. This is the inherent opportunity of climate change.

B. Porro

Bruno Porro
Chief Risk Officer, Swiss Re

Adjustment to climate anomalies: artificial cross-country ski run in the Swiss Alps in the winter of 2001/2002, which suffered a severe lack of snow.

Weather and climate

Public discussion tends to reduce the issue of climate change to elementary questions: "How pronounced is global warming, how serious is it, and whose fault is it?"[1] Such questions implicitly assume a linear causal relationship in line with the perpetrator principle, which implies that the threat of damage could easily be averted if the perpetrators were prevented from triggering the cause.

In fact, however, it is impossible for methodological reasons to prove a single causal connection between, for example, the rise in the earth's mean annual temperature on the one hand and weather-related damage on the other, to say nothing of quantifying it. For example, if storm damage in a certain region were to increase, this would not necessarily imply that storms have become more frequent or violent. Weather observations to date, at least, have failed to show that this is the case anywhere in the world[2]. The increase in damage could already be explained in terms of increasing population density and value concentration. Even if the storm intensity or frequency could be shown to increase in future – which is probable in individual regions if atmospheric warming continues[3] – it would still not be possible to clarify beyond doubt to what extent this increase was a consequence of global warming or other climatic factors. And even if this were possible, the question would still remain as to what extent the increase in damage was attributable to natural or human-induced climatic factors or to the above-mentioned social factors, and who should be held accountable.

There is no such thing as unnatural weather

Weather conditions are not determined by simple, linear cause-and-effect relations. They are the product of a complex system in which many different factors interact in such a way that even minor changes on the causal side can bring about unforeseeable consequences on the effects side. This makes it impossible to explain the occurrence of individual weather phenomena in terms of a single cause. It cannot be thereby deduced, however, that human influence on weather mechanisms is harmless. Any change in the natural conditions – which include weather processes – triggers risks. However, it would be wrong, or at least unrealistic, to expect that it is possible to establish the degree to which an individual meteorological phenomenon is natural or man-made. There is no such thing as unnatural weather.

Weather consists of real phenomena
Climate is a mathematical artefact

Weather and climate are two fundamentally different things. Weather consists of real phenomena which we perceive through our senses and can generally measure precisely: heat, warmth, humidity, wind force, lightning, rainbows, fog, clouds, polar lights, snow, hail and many other meteorological phenomena. Climate, on the other hand, consists of figures. That is, it is neither sensorially perceptible nor measurable in a real sense. Climate is "a mathematical artefact that does not occur in reality"[4]. Weather and climate have as much or as little in common as trade at a local market has to do with economic indicators.

Climate is keeping a record of weather

Climate is keeping a record of weather conditions. Since the weather can change within minutes, continuous measurements would provide unwieldy sets of data. If a meteorological station were to take hourly readings of temperature, relative humidity, air pressure, wind speed and precipitation, there would be more than 1.3 million individual measurements over a period of 30 years – the length of time required to make meaningful statements about climate. The obvious solution, therefore, is to reduce this flood of data by making less frequent measurements and calculating mean values. Many meteorological stations take only four air temperature readings a day to calculate the daily mean temperatures and use this data to obtain monthly and annual figures. Climate is the weather average.

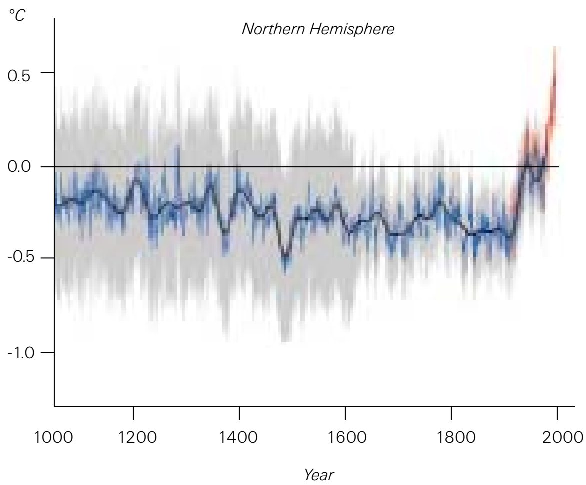


Figure 1
Deviation of annual mean temperatures from the average of the period 1961–1990 (reference line): The red curve indicates temperature gauge values, the blue curve shows data reconstructed from annual rings on trees, corals, ice and historical recordings. The grey area indicates the fluctuation margin of the averaged data. (Source: IPCC).

Weather changes constantly
Climate changes gradually

This method of calculating mean temperatures necessarily fails to consider many short-term fluctuations and extreme levels. Two identical mean annual temperatures do not represent two identical weather curves: one could refer to a year in which the winter was mild and the summer cool, and the other a year in which an extremely cold winter was followed by an exceptionally hot summer. Similarly, two identical annual precipitation figures often conceal quite different events. The one year may have had some rain every month, while in the other, months of drought may have been followed by torrential rain and devastating floods. Weather changes constantly, climate gradually.

It is not the climate that makes the weather, but the weather that makes the climate

Conversely, climate does not facilitate any direct conclusion as to what kind of weather can be expected. The fact that for many years the average precipitation in Tenerife during summer has been only about 3 mm is no guarantee for a rain-free holiday. It merely makes this more probable than in Cherrapunji, India, which has the world's highest precipitation figure with a June average of 2922 mm, or almost 3000 litres per square metre. It is not the climate that makes the weather, but the weather average which defines the climate.

The climate of a given area indicates the setting in which local weather normally occurs, just as a balance sheet indicates factors about a company's size and assets, and about its prospects for future development. Even so, climates and balance sheets are not forecasts, which require far more than a purely statistical observation of the past. Forecasts depend on the most precise knowledge available regarding inherent operating mechanisms.

Statistics never indicate why something happens

Meteorology is the science of atmospheric physics; it examines the causes of weather processes. Classical climatology measures the distribution of the individual results of these weather processes in space and time, and draws conclusions such as: hurricanes are most likely to occur in summer and autumn and generally veer north from their initial westward course across the Atlantic at such an early stage that they rarely cause any serious damage on the East Coast of the US. Whether that is always the case, exactly when the next hurricane will form, and what track it will take, cannot be deduced from these observations. Statistics never indicate why something happens.

This is why one of the tasks of meteorology is to establish as precise an understanding as possible of the physical processes underlying tropical cyclones. For example, that they are spawned only over warm seawater of at least 26° C, and that their tracks are determined by the earth's rotation and extensive temperature and air pressure differences. This substantiated knowledge permits their tracks to be calculated with sufficient precision, even if only a few hours in advance. In this way, coastal regions can be evacuated before these cyclones make landfall. This type of track prediction has already saved millions of human lives. Modern weather forecasts are thus based not on statistical observations, but on an – admittedly limited – understanding of physical factors. Precisely this is the difference between scientific weather forecasts and folk sayings, which are little more than statistics in rhyming form.

Climate follows natural mechanisms, not statistics

The attempt is frequently made to interpret future climate on the basis of previous statistical observations. Some extrapolate the demonstrable warming of recent decades to predict a state where the earth becomes too hot to support life, while others argue that until now, every warm phase has been followed by a cooling period, and consequently, this will also be the case in the future. Such fallacies could have equally fatal consequences as, for instance, not evacuating a coastal region despite an approaching cyclone, simply because the region has never been struck by a cyclone before. The weather obeys natural mechanisms, not statistics.

Statistics are a valuable mathematical aid for establishing the areas in which it is worth examining causal relations. The observation that tropical cyclones evidently never occur in winter initiated the systematic search for the now familiar conditions which spawn such meteorological leviathans. Even so, there is still a tremendous difference between recognising the frequency and understanding the rule.

No reliable forecasts can be derived from purely statistical climatic observations

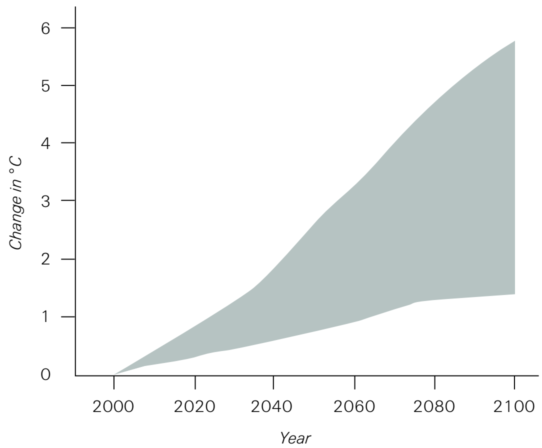
As long as these rules, ie these causal relations, remain unknown, there can be no certainty whether the atmospheric system will continue to behave exactly the same way in the future as it has until that point. We only know *how* the system behaves, but not *why* it behaves as it does. Consequently, we are unable to assess whether the causes of its behaviour will remain the same or whether they will change. Statistical observations alone do not enable us to predict whether or how the climate will change.

Greenhouse effect

Forecasts are based on recognised cause-and-effect relations. For example, this applies to the fact that greenhouse gases, such as carbon dioxide, permit unhindered passage of short-wave sunlight, yet absorb some of the earth's long-wave thermal radiation, which leads to atmospheric warming. This gives rise to the hypothetical conclusion that an increase in the concentration of such greenhouse gases in the atmosphere intensifies the natural greenhouse effect and hence global warming.

This qualitative difference between statistical observation on the one hand and cause-and-effect relations on the other is crucial for a correct understanding of the climate problem. Modern climatology does not tell us that the climate has changed and that consequently, weather conditions will change. It states exactly the opposite, ie that the chemistry of the atmosphere has been altered. This will lead to changed weather conditions, which, in turn, will be reflected in a climate change.

Figure 2
Possible temperature development until the end of this century: The broad fluctuation margin results from various climate models and differing assumptions on future emissions of human greenhouse gases. (Source: IPCC).

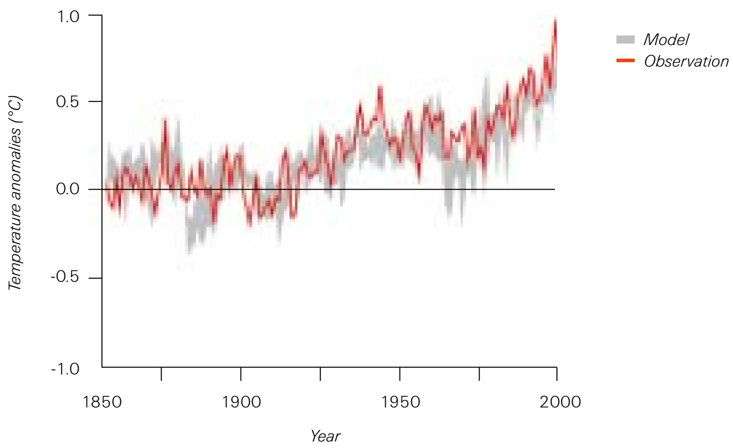


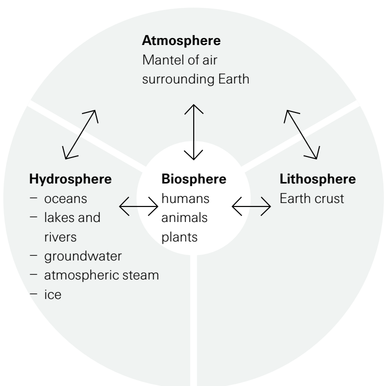
Climatic models are testing grounds

Experiments are required to prove or disprove such hypotheses. Since the complex global weather machine cannot be reconstructed in miniature, the necessary experiments must be conducted with climatic computer models. Mathematical reproductions of atmospheric processes make it possible to study how changes in individual parameters – eg atmospheric carbon dioxide content – affect other variables, such as mean annual temperature. If historical periods are simulated in the experiment and the result is compared with the actual climatic data of this period, it becomes clear how reliably the model reproduces the real processes. Thus, climatic models do not serve primarily to generate prognoses, but to identify causal relationships.

Figure 3 illustrates impressively how accurately today's climatic models reproduce the effects of both natural and human-generated climatic factors. This alone justifies the assertion that the higher the greenhouse gas concentrations, the greater the greenhouse effect, and the warmer the atmosphere.

Figure 3
Currently available climate models would have predicted the climate since 1850 largely in line with the development that was actually recorded. (Source: IPCC)





Nevertheless, the development of the climate remains uncertain to some extent. Although greenhouse gases are an important climatic factor, they are not the only one. Weather conditions are subject to many different spheres (atmosphere, hydrosphere, lithosphere, biosphere), all of which change to a greater or lesser degree over short or long periods. These changes may be periodic, eg triggered by solar activity, or permanent, eg continental drift. Further, there are complex interactive relationships between many of the elements contributing to weather conditions. The effects of these elements can mutually strengthen or weaken each other in ways that are not yet completely understood. Moreover, some factors occur only periodically. Volcanic eruptions, for example, release sulphate particles that cause a sudden and massive global cooling which is, however, only temporary. The combined effect of all these sources of instability is such a high degree of variability that the earth's atmosphere could become warmer even faster and more intensely than previously feared. Or it could grow cooler instead – which is equally possible, at least theoretically.

Incorrect climatic data?
What is the role of the sun?

Besides the greenhouse gas hypothesis, there have been other attempts – also scientifically founded – to explain the observed rise in the average global temperature. They range from a fundamental criticism of the reliability and hence comparability of historical and current temperature readings to some entirely novel theses concerning solar cycles. According to the latter, radiated solar energy fluctuates much more radically than previously assumed, which could lead to rapid changes between cold and warm periods on earth. Only further research will reveal which assumptions are correct. Until this time, the remaining uncertainty will continue to be an important part, if not the actual core, of the problem.

Summary

The certainties and uncertainties can be summarised as follows:

Climate is the weather average. Climate change means that the average weather is subject to change. The global warming hypothesis is based not on statistical climatic observations, but on scientifically based assumptions concerning the cause-and-effect relations between greenhouse gases and the earth's thermal balance. Nevertheless, it is not known exactly *how* climate changes. In view of the variability of natural climatic factors, the temperature-raising effect of human greenhouse gases can be unforeseeably reinforced, compensated or – for a certain period – even overcompensated. It is known, however, *that* the climate must change in any case since weather-generating factors have changed and will continue to change.

Although we do not know precisely *what* the human contribution has been or will be to previous and future climatic changes, we do know that humans *do* influence weather conditions. After all, many of our activities consist of deliberately or unintentionally changing our habitat and the weather-shaping spheres. Wooded areas which have been cleared to create land for cultivation will naturally no longer have a forest climate. Similarly, if we alter the chemical composition of the atmosphere, this fact cannot fail to affect the physical processes occurring within it.

There is no way of telling *how* climate change affects humans for the simple reason that such knowledge would require certainty regarding the direction and extent of future climate trends. But we certainly do know *that* climate changes have an effect. Why else would we have tried to adapt ourselves to the various different climatic regions by adopting so many different ways of life, economic activities and technical skills?

We are faced with two fundamentally different kinds of risk. First, there are all those risks arising from the variability of the climate as such. Second, there are the special risks that result from the human impact on the climate. Different kinds of risk require different strategies: weather and climate protection.

Weather protection

Due to the impossibility of creating a constant climate, the only way of dealing with the risks related to variability is the optimum adaptation of our socio-economic and technical systems to the anticipated weather conditions. This is weather protection.

Climate protection

By contrast, the most effective way of dealing with the risks posed by the human impact on the climate is to reduce the degree of human intervention in the natural climatic system. This is climate protection.

No matter how effective climate protection is, it cannot be a substitute for weather protection. Conversely, climate protection cannot be rendered superfluous by optimising weather protection. Of course, a crucial connection exists between the two risk complexes. There is a danger that human intervention will accelerate and intensify natural climate changes to such a point it will become impossible to adapt our socio-economic systems in time.

The human race can lead itself into this climatic catastrophe – or it can avert it, since human beings are capable of learning and adapting.

Adjustment to extreme weather conditions: polar research scientist in perpetual ice.

Risks and opportunities of climate change

Risk is possible loss, and opportunity is possible gain. Since climate is the weather average, we can apply the term climate risks to a possible increase in average weather-related damage and losses. By analogy, climate opportunities comprise the possible increase in the average weather-related gains in material or emotional terms.

Those who simply rely on being able to benefit from the opportunities are leaving their destiny to chance. By contrast, those who systematically endeavour to gain more than they lose must consciously examine the risks and opportunities. They must identify possible weather-related losses and gains, and consider how the impact of weather conditions can be favourably influenced.

Even slight deviations from previous weather conditions can have farreaching consequences

Much more is involved here than the question of a possible increase or decrease in the frequency and intensity of extreme meteorological phenomena such as hurricanes or tornadoes. Although serious, an accumulation of natural catastrophes is merely a *possible* consequence of climate changes. By contrast, "normal" weather conditions are *certain* to change; after all, climate change is defined as a "change in average weather conditions": a few rainy days less per year, a somewhat lower incidence of frost, a few more particularly warm days. This may sound relatively harmless, but it is not, as the following example shows.

Example: Summer of 1995 in England and Wales

From November 1994 to October 1995, England and Wales experienced an unusually warm period. The average temperature during this period was 1.5° C higher than the mean figure for the years 1961 to 1990, while that of the months July and August was as much as 3° C higher.

According to a study by Jean P. Palutikof[5], the mortality rate in July and August 1995 rose by 5% and 1%, respectively, as a result of the heat, although for the entire period, it was significantly lower than the average of many years standing because of the mild winter. Palutikof calculates that a warming of the mean annual temperature by 1° C would reduce total mortality in England and Wales by 7,000 fatalities a year.

Depending on local soil conditions and other factors, the 1995 grain harvest was exceptionally good in some areas, whereas in others there were substantial crop failures. Particularly hard hit were cattle breeding and trout farming. Overall, British farmers sustained losses of GBP 180 million due to this climatic anomaly. Natural gas and electricity consumption dropped sharply because of reduced heating requirements, and recovered only slightly in summer as cooling requirements increased. The net losses of the power industry – or savings, as far as the consumers were concerned – was GBP 355 million. Among the winners was the beverages industry, with a sales increase of GBP 130 million, while clothing retailers suffered losses exceeding GBP 380 million. The insurance industry was obliged to pay additional claims amounting to GBP 350 million as a result of damage to buildings due to drought-induced subsidence.

Climatic anomaly: a striking deviation from previous weather conditions

Such studies – which are still few and far between – clearly show that even unspectacular climatic anomalies, which the general public perceives as "unusual", rather than "catastrophic" weather conditions, can cause losses on a scale normally associated only with natural catastrophes. All totalled, the losses and damage of the warm summer of 1995 in the UK exceeded GBP 1.5 billion. The unusually warm summer of 1992 in northern Germany caused crop failures generating losses of approximately DEM 4 billion at the then prevailing price levels. The government spent more than DEM 2 billion to compensate those who were faced with financial ruin[6]. Nevertheless, neither event was rated by the public as a calamity: some 70% of 1800 respondents polled in North Germany actually found the "summer of the century" in 1992 as "beneficial to health"[7].

Climatic anomalies may have favourable or adverse effects, depending on the system concerned

If "extreme" weather phenomena, regardless of their actual consequences, appear much more catastrophic than mere "out-of-the-ordinary" weather episodes, this is perhaps due mainly to the different images of damage they project. Extreme weather phenomena have a clear source and abruptly cause massive damage which receives broad media coverage and is virtually impossible to ignore. This is why the public perceives extreme weather phenomena as threatening events devoid of any positive aspects. Conversely, the impact of climatic anomalies may vary substantially, depending on the system concerned. Not everyone suffers from "particularly warm summers". Many even profit from them or at least enjoy them. Further, many of the adverse effects of such anomalies are difficult to visualise because they generally materialise in private, in seclusion, behind closed doors. In the evening, when the retailer does his accounts; or months after the summer that caused the damage, when the farmer goes bankrupt in winter because livestock feed has become too expensive after the failed autumn harvest. Such ramifications are perceived only by those who are directly affected or who, like Palutikof, deliberately look for them. And even then, only concrete individual cases of minor relevance to society as a whole are observed. Or the consequences are presented in the form of anonymous figures which, at best, give only a general indication of the fate behind them: "Mortality rate rises 5%" or "Government grants emergency aid totalling DEM 2 billion" may be statistically significant signals, but they do not supply any spectacular image of the damage caused.

Normal weather can only change into abnormal weather

Consequently, a "possible increase in the frequency of extreme meteorological events" is self-evidently alarming – if only because the word "extreme" is intuitively associated with "dangerous". By comparison, a "change in the average weather conditions" sounds harmless, because "average" suggests normality. What is overlooked, however, is that normal weather can only change – regardless of direction – into abnormal weather.

Climatologists define a climatic anomaly as "a marked deviation by an individual value from an average figure or from a trend in a time sequence"[8]. From a practical standpoint, anomalies may be understood quite simply as atypical, unusual, out-of-the-ordinary weather conditions which, in light of previous experience, were not to be expected in that form; at least not at that location and at that time of year.

We call this "weather experience" normal because it actually functions as a norm by serving as a basis for innumerable decisions and measures in all areas of life: seasons for the tourist industry, planting periods in farming, stockpiling supplies in preparation for winter, highway inspections for temperature resistance, testing the capacity of water supply systems, the legal imposition of seasonal limitations on the use of spike tires, selecting dates for major sporting events, placing limits on the capacity of cold storage depots, etc.

If the climate changes, there is a rise in the occurrence frequency of anomalies, ie weather conditions to which people have not adjusted themselves because they did not anticipate them. This may have a positive or negative impact in individual cases, but it is never without consequences.

Abnormal weather becomes normal as a result of adaptation

While we might – rather casually – say that extreme weather phenomena always occur at the wrong place and time and that we generally adapt by protecting ourselves as well as we can against the elements, climatic anomalies are only abnormal for as long as it takes our socio-economic systems to adapt to them. Put simply, weather is normal if it is familiar from past experience and we have adapted to it – regardless of how or with what degree of success.

Acclimatisation is adaptation to anticipated future weather conditions

The fact that human beings are able to adapt successfully to the most varied climates and protect themselves against extreme manifestations of the elements, is beyond doubt. However, this is not the decisive point. The problem is that they must by necessity adapt themselves to the *previous* average weather conditions rather than future ones which, after all, are not or only partly known.

So far, we have relied on the fact that future climate corresponds at least approximately to our past experience with the weather. This confidence has been shaken to its foundations because there is no longer any doubt that the climate is changing and will continue to change. At the practical level, the question is not only how to adapt but also, and with increasing urgency, what we should to adapt to, and when to start.

Adapt to what?
Adapt when?
Adapt how?

When, for example, should a farmer switch to drought-resistant cereal strains? When should highways be fitted with a more heat-resistant surface? When should a skiing area be abandoned, when should the insurer adapt his contracts to changed climatic conditions, when should the soft drinks manufacturer expand his production capacity? And when, to give just one more example, is it time to invest billions into raising the height of the flood protection dikes of a port: when the sea level might rise, when it begins to rise, when it has risen – or when a storm flood for the first time claims an above-average number of victims?

There can be no universally valid answers to such questions as long as it is not possible to forecast with any certainty what will happen. What is to be done and when, and whether it is right or wrong, must be decided case by case on the basis of the affected persons' safety requirements and readiness to take risks and in light of their economic resources and priorities.

Probability as a measure of the costs of adaptation

In any case, however, it would be wrong to completely ignore possible developments simply because they are regarded as not very probable – or not sufficiently probable to justify an examination of their possible consequences. Probability itself should not be a criterion for deciding whether or not to prepare ourselves for an event, but only for how we prepare ourselves. Instead of asking what climatic trend is the most probable according to the latest research and preparing for that specific eventuality, we should adapt ourselves to meet all possible developments as a matter of principle, varying only the expenditure in relation to probability.

Example: flexible flood protection

Flood protection can be used as an example. How high should the protective dams be? Sufficiently high for a once-in-a-century event or for an event which occurs only every two centuries? Whatever is decided, if the climate changes, floods may suddenly occur more frequently than expected. This is why modern flood protection involves different measures for events of varying probability. For the rare event of the existing dams being insufficient, for example, the noise protection walls of a motorway in a valley may be designed in such a way that the road can be used as a drainage channel. For the even rarer event of this being insufficient, recreation facilities, sports grounds and similar areas may be designed to also serve as retention basins which could be flooded in case of emergency. And, for the even rarer event, a preventive decision may be made as to what inhabited areas should be sacrificed first in an effort to keep the overall damage as small as possible. Even these measures will not guarantee absolute protection, but they will make the damage controllable and provide a means of coping with climate-related surprises.

Climate variability
Forecasting skills
Responsiveness

When and how we will have to adapt to weather-related damage and losses depends on how quickly or abruptly climate can change, how reliably this development can be predicted, and how fast the socio-economic systems are able to adjust themselves to the changed climatic conditions. Climate variability, forecasting skills and responsiveness are the three crucial factors of risks and opportunities posed by climate changes.

This gives rise to a general interest in climate protection. The more intensive and varied human intervention in the chemistry and physics of the atmosphere becomes, the greater the risk of increasing the natural climate variability and the wider the range of possible weather conditions to which adaptation will be required.

Climate protection

The possibilities of climate protection – especially the reduction of greenhouse gas concentrations in the atmosphere – are sufficiently well known so that only two concepts will be offered here. The first is that everything which joint efforts in climate protection fail to achieve must ultimately be borne by the "losers" of a climate change. The latter, on the other hand, are not likely to take this lying down. This is why it would be short-sighted to confine efforts to being on the winning side. In an increasingly globalised world, the aim must be to shoulder the consequences of our joint actions mutually and reach a compromise recognised as being just – either by spreading the burden of damage prevention fairly or by sharing the losses.

The second point, as illustrated by current IPCC studies, is that while climate protection is necessary for successfully handling the climate issue, it is not sufficient. It is necessary because any further intervention in the chemistry and physics of the atmosphere could increase climate variability to such an extent that the consequences might be impossible to overcome no matter how fast we adapt. It is not sufficient since climate is variable by its very nature, and the task of adapting technical and socio-economic systems to changeable climates must be faced in any case.

IPCC: Intergovernmental Panel on Climate Change

To summarise, the fact that human beings are capable of adapting to climate changes is just as much a truism as is the assertion that there are winners and losers in the case of climate changes. Yet for the individual person, family, community, city or nation, all that counts is what side one is going to end up on. But the question of the individual's own risks and opportunities is one for which there can be no hard-and-fast answer. This is because the same weather has different effects on different systems, and even very similar systems – two businesses in the same industry, for example – can differ considerably from one other in terms of their susceptibility to weather conditions.

The key to solving the climate problem therefore is to recognise that it affects us all. Only when individuals understand what climate changes means for them personally are they able to understand what measures are required to reduce risks and take advantage of the opportunities – whether through supporting climate protection measures or by responding to changeable climates.

The realisation of being personally concerned should not, however, be confined to extreme meteorological phenomena. On the contrary, most people will experience the consequences of climate changes not primarily in the form of natural catastrophes, but as consequences of climatic anomalies which may have favourable effects but may also constitute an existential threat. Hence, it is not enough to examine a potential increase in extreme meteorological phenomena – an effort must also be made to uncover the indirect, concealed effects of climate changes. Since they vary greatly from system to system, the resulting risks and opportunities can be detected only by those who are personally affected.

Adjustment by deriving benefit from extreme climates: aircraft depot in the very dry Mojave desert, California for airliners temporarily out of commission.

What changes when the climate changes?

According to the IPCC's Third Evaluation Report[9], the global mean annual temperature may increase by 5.8° C by the year 2100. The task of a risk analysis is not to examine the accuracy and reliability of such forecasts. This would involve either conducting active climate research to confirm or disprove the underlying theses and the conclusions derived thereby on the basis of new scientific findings. Alternatively, the analysis would deteriorate (as is always the case when science is unable to provide any proof for the correctness of a given thesis) into an assessment not of the content, but of the credibility of the scientists themselves.

Such polemics are unproductive because they divert attention and resources to issues which are currently irrelevant. For our decisions and actions, it is unimportant whether the prognosis turns out to be true. The sole decisive factor is that it could be correct. As long as we keep trying to decide whether the prognosis is correct, we will be unable to identify either the risks or the opportunities of the forecast development, to say nothing of either overcoming or taking advantage of them. The purpose of a climate forecast is not to predict the future, but to help shape it.

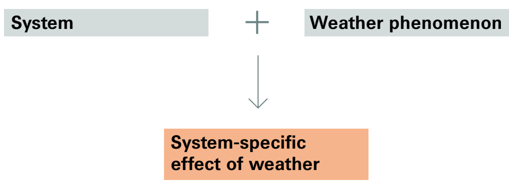
Weather is a combination of physical states

In the first place, this necessitates a *proper* understanding of how weather itself operates. Viewed objectively, weather is a combination of physical states, for example temperature, density, pressure, humidity and the speed of air currents. Each of these states has a specific effect, which varies according to intensity. Hot air gives us warmth, cold air deprives us of warmth. Such physical effects are the same for all systems: rain always brings humidity, wind always has a desiccating effect. The consequences differ according to the system concerned. The same weather conditions may have positive effects on one system and negative ones on another. A cactus cannot survive in a rain forest, while a mahogany tree transplanted to the Sahara would perish instantly.

Weather sensitivity: How do weather conditions affect a given system?

The initial step, therefore, is to ascertain what kind of weather has a favourable effect on the system to be examined and what kind has an adverse effect, for example, by establishing a ratio between the earnings of a beverage manufacturer and a temperature chart. Since economic success does not depend purely on weather conditions and these in turn do not consist merely of temperature fluctuations, the correlation between variations in earnings and temperature will not be very high.

Figure 4
The impact of weather phenomena on a system generates a system-specific weather effect.



Individual weather phenomena must be assigned to concrete system variables to obtain meaningful results. This blends weather conditions and their system-specific effects into a characteristic weather effect, which results in such terms as the German *hitzefrei* (school recess due to extremely hot weather), "bathing weather" or "harvest weather". Modern variants of such terms are "heating-degree days" and "cooling-degree days", which power utilities use to describe the fluctuations in energy requirements dictated by temperature.

Figure 5
A selection of system parameters and weather phenomena whose interaction could generate system-specific weather sensitivities.

System parameter

Well-being
Productivity/efficiency
Creativity
Life expectancy
Fertility
Cash flow
Revenue
Profit
Demand
Sales
Turnover
Attendance figures
Punctuality
Reliability
Quality
Durability
Resilience
Error rate
Incidents
Outages
Accidents
Damage
Sickness rate
Mortality rate
...

as a function of

Weather phenomenon

Weather phenomenon
Temperature
Humidity
Air pressure
Visibility (fog)
Precipitation
– rain
– snow
– hail
Snow depth
Discharge
Dry periods
Rain periods
High pressure areas
Low pressure areas
Weather changes
Wind speed
Storm tracks
Lightning frequency
...

Since it is obviously impossible to investigate all conceivable weather effects, it is advisable to focus on critical system properties, ie those that have the greatest importance for a system's security or output. For example, while energy prices play a role in all systems, they are certainly not the decisive factor in determining the economic success of a winter sports resort. In this case, therefore, the central issue does not involve investigating the extent to which energy prices are influenced by the weather. Instead, the first step will be to ascertain how the weather affects the number of overnight stays or ski lift rides per hour, and then to determine which weather parameters are correlated with these figures – days with a certain minimum snow depth, for example. Selecting the combination to be investigated is hence *always* a system-specific question. It would hardly make any sense to investigate the correlation between the snow depth and the number of visitors to an outdoor swimming pool.

Even so, studies should not be confined to obvious connections, such as the influence of weather-related harvest yields on raw cotton prices. Less obvious connections may also be worth examining. How do weather conditions influence consumer behaviour? At what temperatures is wool preferred? At what wind speeds do people prefer synthetic clothing? To what extent do beverage sales depend on humidity as well as on temperature? In what kinds of weather do a restaurant's food supplies spoil regularly because fewer customers come than expected? Is the number of traffic accidents in winter determined by the number of days with icy roads? Or by the frequency of abrupt switches from good to bad road conditions? Or are fewer accidents caused by black ice if the roads are permanently ice-bound?

Suitable parameters are another precondition for meaningful results. Is there a correlation between the number of burst pipes and the number of frosty days per year, minimum temperatures attained, or the average temperature or duration of frost periods? The answer depends on the prevailing construction method. For example, how well are water pipes insulated, and at what depth are they routed? In another case, a farmer, for instance, is less interested in the number of days in the year when it does not rain, than in the number of days in succession without rainfall.

Making weather effects countable

All these questions are designed to make weather effects countable, or to use climatic data to calculate their frequency to date. This is used in turn to deduce the consequences of a climate change, or a change in the frequency distribution of these weather effects.

Although this will still not make it possible to predict future climate, it will show how sensitive the system in question is to climatic anomalies. If key system parameters can easily be influenced by the weather, even slight deviations from previous weather conditions can have serious consequences. If, on the other hand, the system is largely "weather-resistant", even a radical climate will have only negligible direct consequences.

Weather sensitivity studies show risks and opportunities

The real value of such studies is that they show how weather operates. This in turn may reveal entirely new opportunities of taking advantage of favourable effects and avoiding unfavourable ones. The operators of a large amusement park drew an innovative conclusion from the basically mundane discovery that there was a direct correlation between their power consumption and sunny weather since the latter determined the number of visitors. They built their own solar power station because they could be sure that they would need a lot of energy only when the weather was sunny.

Sensitivity studies often lead to surprising results. The frequent lack of snow in the Swiss Alps is generally regarded as a consequence of climate change. A detailed study[10] has shown, however, that "many problems of the tourist industry that are too readily associated with climate change are solely attributable to the existing natural variability in the weather conditions", since winters with low snowfall are by no means a rarity in Switzerland. Hence, the recommendation that "those in charge of tourism give serious consideration to the consequences of low snowfall", particularly since this problem may become aggravated. If global warming continues, "only 44% of the skiing areas will have guaranteed snow in future, compared with 69% today".

The purpose of sensitivity studies is not just to prevent damage and losses. The real intention is to improve our understanding of the interplay of weather, humans and nature, eg to make better use of the weather, protect ourselves better against storms or make more reliable assessments of the specific consequences of human intervention in the natural climatic system.

Weather sensitivity studies must be system-specific

The problem is that sensitivity studies must be system-specific to provide useful results. It is no help to a construction company to know how global warming affects the fishing industry. And meteorologists or climatologists cannot find out on their own what concrete consequences a series of dry summers will have for the shipping trade. Sensitivity studies are supposed to show how and where the weather affects specific interests – and each system must take care of its own.

That is why sensitivity studies for individual regions or industries must be interpreted with due caution. They can only indicate the scale of the anticipated losses and gains resulting from climate changes, for example for the US recreation industry.[11] In the case of winter sports, a warming trend would definitely result in reduced earnings, while golf would remain unaffected by climate changes from an economic standpoint and boating would profit. Forecasts for individuals, companies or locations cannot be derived from such studies, which are now available for most economic sectors, since the actual effects ultimately depend on how those affected will adapt. These studies can, however, serve as a basis for system-specific studies.

Personalising the weather

Those who consider the effort of investigating their "own" weather sensitivity too great can join forces with those equally affected, whether as members of associations or interest groups formed especially for this purpose. The optimal method will emerge after the initial step, which consists of "personalising" the weather. What is the importance of weather to me, to what I attach value, and to my areas of responsibility?

Adjustment by showing flexibility: In the event of a flood, this bridge across the Saltina river in Brig, Switzerland, is raised to prevent build-up of water and scree. This reduces the risk of flooding.

Climate change and the insurance industry

In a constant climate, the sum of all weather-related losses and damage would be calculable over long periods. The more variable the climate, the more variable the extent of the damage per time unit, and the more difficult to estimate weather risks reliably. For the insurer, this translates into an increased risk of being ruined by a sudden, unexpectedly high loss burden.

The insurance industry can react to this only by increasing the burden on the individual insured party, whether by limiting the benefits paid in the event of a loss, by raising premiums or by demanding greater efforts to mitigate the extent and probability of the damage or losses to be insured.

It would therefore be entirely wrong to assume that the insurance industry could contribute to mastering climate risks by shouldering a larger share of the loss burden. The fact is that extremely high claims resulting from natural catastrophes can overtax individual insurance companies. In the medium term, however, the insurance industry must pass back excessively high burdens to the insured. The idea of insurance is not to bear losses, but to spread them throughout the insured community on the basis of solidarity.

Solidarity also requires systematic loss avoidance

This will work successfully only as long as all members make every possible effort to prevent losses, thereby ensuring that loss occurrences are the exception rather than the rule. This is the whole point of adapting to the climate. We shape our lives and our socio-economic systems in such a way that the average weather conditions only rarely trigger damage or loss. If the climate changes, losses that were previously an exception may become the rule.

If losses become the rule, insurance makes no sense

Solidarity then no longer makes any sense. If individual members suffer regular losses because they have failed or were too slow to adapt to the changed climate, the other members will not be prepared to share the burden, especially if they themselves have made great efforts to adapt to the new conditions. And if damage becomes the rule for all members because they were unable to adapt in time, there will no longer be any non-victims who could bear a part of the burden. In an extreme scenario, everyone would pay for his own loss or damage, in which case insurance would not be necessary.

Insurance alone will not reduce the total loss burden. The aim must be to prevent an increase in weather-related damage and losses as a result of climate changes – not just in the interests of the insurance industry, but in the interests of everyone.

The insurance industry cannot solve the climate problem, but can help to handle it

The total loss burden is determined by how we intervene collectively in the natural climatic system and how we cope with the risks of natural and man-made climate variation. For both of these cases, the insurance industry is no more and no less responsible than any other industry. However, due to its special experience in dealing with risks, it can make a decisive contribution to comprehensively mastering risk.

Identifying risks

Firstly, the industry can do this by identifying risks, especially those which are not yet the subject of public debate. For example, it can point out that climate changes do not just become a threat when extreme meteorological phenomena accumulate. Even apparently harmless climatic anomalies, such as a "particularly warm" summer, can have far-reaching consequences. While they do not affect everyone, they can pose as great an existential threat as weather-related natural catastrophes.

Secondly, the industry can contribute towards ensuring that identified risks are actually perceived by those affected. This means making concrete linkages, the aim being to show where and how climate changes affect individual interests. This is why a systematic search for the individual effects of climate changes is a sound approach. A feasible procedure is offered by the sensitivity studies outlined in the section, "What changes when the climate changes". Those who have understood what average weather conditions mean for their own situation and areas of responsibility can better identify and assess how changed weather conditions would affect them.

Analysing risks

Thirdly, the insurance industry provides decisive assistance in analysing identified risks. How do weather-related damage and losses occur? What influences their extent and probability of occurrence? How can they be qualitatively described, or even better, quantified? Answering such questions is the daily business of insurers and, accordingly, they have the relevant expertise and proven procedures, databases and tools. But again, the principle applies that those affected should analyse their own risks or at least be closely involved in this pursuit. Only if the origins of the results are known can a proper assessment be made to arrive at the right conclusions.

Mitigating risks

Fourthly, the insurance industry can assist in reducing climate risks by supporting a practicable approach to climate protection in line with the principle of sustainability. In its capacity as an investor, it is able to promote the transition from fossil to renewable energy forms, and to play an innovative role in developing novel, more flexible forms of adjusting to the climate. Above all, insurers can do this by repeatedly pointing out that weather-related damage and losses can be systematically avoided and the manner in which they can be prevented. They can then demand, in the interests of the insured, that these possibilities of adaptation and protection be actually implemented.

Transferring risks

Lastly, it is the task of the insurance industry to facilitate insurance for weather risks despite climate change and to continue providing cover which is both adequate and affordable. Accomplishing this will require more than merely waiting to see how claims will trend and then react if necessary with known measures. Nor are the insurer's climate risks confined to unexpectedly high extreme weather damage. If average weather conditions change, the average weather-related claims also change: from mortality and sickness rates to industrial, recreational and traffic accidents on land, on water and in the air to manufacturing defects, factory outages or large-scale bush or forest fires with the relevant consequences for health, environment and economy – to mention just a few examples. Climate risks affect all insurance categories, not just traditional natural perils insurance. Changes in climate mean changes in habits and economic activities. Entire markets can disappear, for example, if winter sports regions are abandoned and there is no longer a need to insure ski lift operators against third party claims. Meanwhile, new and as yet unforeseeable insurance requirements will arise, or dormant issues suddenly acquire an explosive topicality. A likely answer to a series of failed harvests caused by climate change might be the increased use of correspondingly genetically modified crops.

The insurance industry must recognise the effects of climate change at an early stage

Both for its own protection and in the interests of the insured, the insurance industry is also called upon to foresee the indirect consequences of climate changes at an early stage so as to adapt itself, its products and those insured to the development in time and be able to provide the insurance cover required.

The practical problem involves the lack of claims histories, which could be statistically evaluated and extrapolated into the future to yield a reliable estimate of the total expected claims burden. This would form an acceptable basis for distributing the burden among all concerned: precisely how the climate will change is not certain. No one knows how climate changes will affect complex, closely interrelated and increasingly globalised socio-economic systems, or how the latter will react in turn. And it is impossible to estimate what damage and losses will occur if we do not succeed in adapting in time.

This confronts the insurance industry with the same key question as everyone else: adapting to what?

This problem certainly cannot be solved by the insurance industry making one-sided assumptions about the future development of insurance claims, however objectively established. This would only result in doubts being cast on these scenarios as well as on all other climate forecasts. This could be perceived by some as panic-mongering, by others as playing down real threats.

Risk consensus

What is needed is risk consensus – an agreement on what climate risks are, how they are to be handled, and how the resulting burdens are to be shared. This consensus cannot be reached by coercion, but by persuasion, by blending the most varied interests, standpoints and requirements into a common, overriding goal.

This is why Swiss Re participates in the political debate on climate protection.[12] This debate will determine the fundamentals for developing, adopting and implementing practical risk handling measures.

However, many individuals have not yet joined in this debate – whether because they see no realistic possibility of making a difference, or because they do not feel affected, or at least not directly. The purpose of this publication is to draw attention to the individual risks and opportunities presented by climate changes. It shows how the often necessarily abstract forecasts of climatology can be related to concrete practice, thus making clear how we are all affected. Climate – like everything else – is only really interesting when an individual's own interests are visibly at stake.

Adjustment to average weather conditions: utilising wind for power generation.

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Title:
Opportunities and risks of climate change

Author:
Christian Brauner

Editing and production:
UC, Technical Communications,
Chief Underwriting Office

Translation:
Group Language Services

Graphic design:
Galizinski Gestaltung, Zurich

Photographs:
Title: Swisspress, New York and Prisma, Zurich
Page 4: Keystone, Arno Balzarini
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