Rev. sci. tech. Off. int. Epiz., 2008, **27** (2), 319-330

Predicted climate changes for the years to come and implications for disease impact studies

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Summary

The paper presents a review of the current ability of the climate modelling community to produce predictions of future climate change. Predictions for the next few decades are reasonably robust, whereas predictions for later time periods depend on uncertainties in climate model structure and on the unknown future course of greenhouse gas emissions. Some regional features are noticeable; however, meaningful interpretation of these can only presently be made at spatial scales that are considerably larger than those required for making sound estimates of the effects of future climate change on animal health. The implication is that current climate change predictions should be considered indicative rather than accurate.

Keywords

Climate – Climate change – Modelling – Prediction – Weather.

Predicting 21st Century weather

When someone first starts thinking about the climate, their first question is usually 'What is the difference between weather and climate?' The answer is often considered quite basic: the climate is the average weather (at a given place and time of day and year). Thus, while the weather can change from minute to minute, the climate is constant from year to year. But this question is in fact much more perceptive: how can we be predicting climate change when the climate is constant?

Edward Lorenz, a central figure in the development of numerical weather prediction, said instead that 'climate is what you expect, weather is what you get' (11, quoting Robert Heinlein, in turn probably quoting Mark Twain). The climate is, then, all of the states of weather that are possible subject to certain constraints external to the climate system, i.e. for which there are no meaningful feedbacks from the weather. Some of these are changing, as described in the previous paper in this issue (Delecluse [5]). So as long as we know how these factors will change and have a 'perfect' model of the climate system, we can then predict future climate exactly, at least in theory.

But of course that climate prediction will never be observed. What will actually occur is not the distribution of all possible meteorological states given the external constraints, but a single realisation: the weather. This realisation will depend not just on the external forcings described by Delecluse (5), but also on what the weather is today, because it takes time for heat, air, and water to be moved about. It matters whether the proverbial Brazilian butterfly has flapped its wings. Thus, as Lorenz said, while we can expect a certain climate, in the end we will get, and thus observe, the weather.

Such distinctions may seem trivial, but they end up being vital in interpreting predictions of future climate. We do not have a perfect model of the climate system, so all of our predictions are inherently uncertain, with the sources and importance of that uncertainty depending on the relation between weather and climate. This paper, a guide to our expectation of future climate change, must be interpreted in this context. With this in mind, the article begins with a description of how predictions of future climate are currently made and then continues with a discussion of predictions of future global climate over shorter timescales (the 2020s) and longer timescales (the 2090s). The paper then examines predictions at a region level and ends with a discussion of implications for animal disease impact studies.

Methods of predicting future climate

Continuation of past trends

Predicting future climate, like any other prediction, requires the use of a model. Under a number of assumptions, a simple extrapolation of a linear trend fit to recent weather may provide a sufficiently accurate prediction. These assumptions may not always be reasonable, however. For instance, the global warming over the past century has been driven mainly by a rise in atmospheric concentrations of greenhouse gases, but it has also been moderated by scattering of sunlight back to space by a rise in sulphate aerosol amounts originating from human activities (6). The balance is expected to change in the future though, with greenhouse gas concentrations continuing to rise but sulphate aerosol amounts being more stable due to smog control measures (17), so a simple linear trend extrapolation may be expected to underestimate future warming. Consequently, the climate community depends primarily on process-based models of the climate system, explicitly calculating changes in physical (and increasingly chemical and vegetative) processes through time.

Simple physical models

Physical climate models can take many forms. The simplest physical models represent a zero-dimensional system with a simple delayed response to an external forcing and can even be calculated analytically for some special cases. Because of their simple structure, such models can be statistically tuned against historical observations, allowing objective probabilistic estimates of future climate change under a given scenario of external forcings (22). Such models are generally restricted to surface temperature, which responds more directly to external radiative forcings, and on global scales, where nonlinearities in feedbacks may be expected to be less important. Simple physical models are useful for diagnosing the effects of uncertainties in future emissions, in physical parametrisations (simple empirical approximations), and in changes on millennial timescales, problems which are unfeasible with more complex models using current computers (15). Notably, climatologists take a similarity of predictions across models of varying complexity as an indication of robustness.

General circulation models

Today, the main model of choice of the climate community is the fully dynamical general circulation model (GCM, also known as a global climate model). These models numerically calculate the exchanges of air, moisture, heat, and radiation on a three dimensional grid of the atmosphere through time. In order to do this, the model divides the atmosphere into grid cells (boxes), calculating exchanges between each of these cells; the model assumes that the weather is uniform within each cell and does not explicitly consider or calculate anything smaller. These atmospheric models interact with a land surface model, which represents storage and transport of soil moisture, river runoff, and the evapotranspiration from the ground and a vegetative canopy. The atmospheric models also interact with comparable models of the ocean and of the sea ice. These interactions are illustrated schematically in Fig. 1. A general description of these models is given by McGuffie *et al.* (13), with more details in McAvaney *et al.* (12) and Le Treut *et al.* (9). Such models have historically been restricted to supercomputers owned by meteorological agencies, but increases in computing power are now allowing them to be run on standard desktop computers (8).

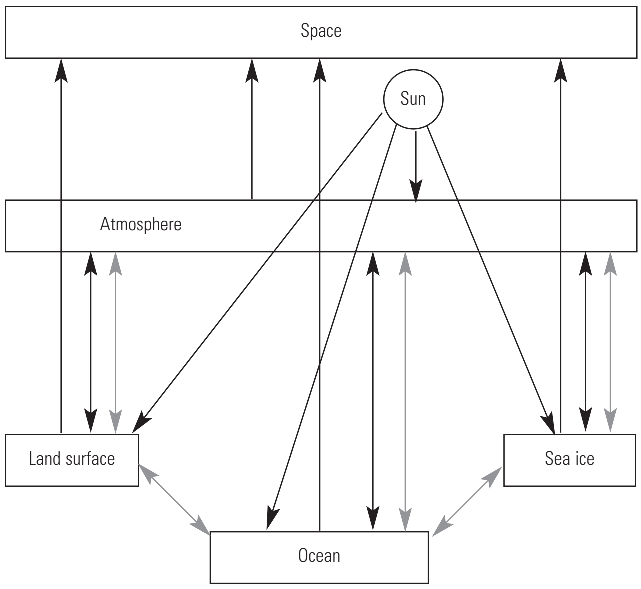

Fig. 1
A schematic diagram of the interacting components of a coupled general circulation model of the climate system
Black arrows represent the transfer of heat, while grey arrows represent the transfer of water, momentum, and heat. The transfer of chemical compounds is included in the grey arrows in some newer models

In principle, GCMs fully encapsulate our knowledge of the climate system. In practice, however, certain shortcuts have to be taken. Most obviously, computing power currently restricts the horizontal spatial resolution (the size of each grid cell) of the atmospheric component to about 200 km (2° latitude/longitude), and the temporal resolution to about 15 minutes, i.e. the model calculates how the weather would change over 15-minute-long steps, and assumes that the weather does not change over smaller time intervals. A consequence of this is that processes which operate at smaller scales, such as mixing of different air masses, must be represented by simple empirical approximations (usually termed parametrisations). Thus, the models do not actually calculate the evolution of individual clouds, but rather represent their collective properties at the 200 km scale as a function of other variables such as humidity. Consequently, differences in future predictions of global climate change by different GCMs often come down to how the clouds respond to increasing greenhouse gas concentrations, and thus differences in the representation of clouds in the different models (20). The oceanic components of the models can have the same horizontal resolution as their atmospheric counterparts but are often run with half that resolution (~100 km).

An important misconception is that a GCM with a horizontal resolution of 200 km produces predictions at that resolution. While technically true, the output is really only meaningful on much larger scales, about 5 to 10 times as large. Because of the complicated nature of fluid flows, the weather over a given area depends on what is happening at spatial scales both larger and smaller than the area being considered. For instance, the weather over southern England depends both on the large-scale pattern of low and high pressure systems and on the small-scale details of local topography and cloud structure. Consequently, the variability in weather over a GCM grid cell relies strongly on the empirical parametrisations which are representing the smaller-scale processes. These parametrisations are only heuristic approximations so we expect the model to perform badly at this scale. However, at several times the model resolution we may begin to suppose that the GCM is truly modelling the relevant smaller processes, although whether this supposition is reasonable is the big unknown in climate modelling. The main message, then, is that current GCM output should be interpreted only at scales greater than about 1,000 km.

Regional climate models

The coarseness of the spatial resolution of GCMs is clearly a major problem for determining the effect of climate change on a disease that is influenced by a much more local environment. There are two main approaches to dealing with this issue (10). One is to actually increase the resolution but only over a smaller region of interest. This is usually done by feeding the meteorological states from a GCM simulation along the borders of the smaller region into a regional version of a GCM, termed a nested regional climate model or RCM (2, 14). Current RCMs typically run at resolutions of about 30 km. Because RCMs are physically modelling the relevant processes, they are allowing for local responses to external forcings that are not possible to consider with coarser global models. The big assumption in RCMs is, however, that anything happening at sub-grid scales outside of the region is not important for the weather within the region. This may not necessarily be the case; for instance, both thunderstorms and waves along the oceanic thermocline in the tropical Pacific, through their role in producing so-called El Niño and La Niña events, can affect weather throughout the tropics and the globe in general. The technical details of how to feed GCM data into a higher resolution RCM are also uncertain.

Empirical downscaling

The other approach for getting around the resolution limit is empirical downscaling, also termed statistical downscaling. This uses relationships noted in the observed record between some large-scale meteorological quantity and a more local variable (25). For a simple example, rainfall over southern areas of England is highly anti-correlated with surface air pressure over a broad area northwest of the United Kingdom. Because this statistical relationship is observed and site-specific, it can easily perform better than the generic parametrisation that represents rainfall in the GCM. Thus, it may even be a more appropriate measure of rainfall in the GCM than rainfall itself, for this example at least. The inference, then, is that this relationship will hold in a future climate. Empirical downscaling has the advantage of simplicity and of effectively being able to resolve the tiniest of spatial scales. In fact, the target variable can just as easily be non-meteorological and in effect all current climate-disease models downscale already in the conversion of meteorological quantities into epidemiological variables. However, empirical downscaling relies absolutely on the availability of adequate and appropriate historical observational records. While this is a requirement of any application of climate model data, the restriction is much more specific with empirical downscaling. Moreover, it implicitly assumes that the relationship between the two scales is independent of the external forcing, which in many cases may not be realistic. This issue becomes particularly acute if future states move outside of the domain of the states observed in the historical record. For instance, the drier soil over continental areas resulting from increased evaporation may change the behaviour of heatwaves in a warmer world (18).

Short-term versus long-term predictions

Predictions versus projections

This paper will not describe future predictions in detail, but rather refer the reader to the comprehensive contemporary Intergovernmental Panel on Climate Change (IPCC) assessment. Summaries and further details are available elsewhere (3, 7, 15, 21). The essential points of the predictions will be given here, but the main emphasis will be on how they are determined and on how to interpret them.

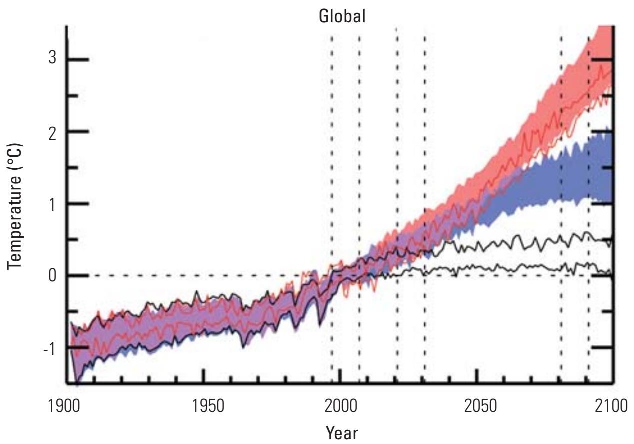

Fig. 2

Time series of annually and globally averaged surface temperature from climate model simulations following various emissions scenarios, as anomalies from the 1997-2006 average

The ranges plotted indicate the very approximate 5th-95th percentile range at each year of:

– 16 simulations from 8 general circulation models (GCMs) following the 'commitment' scenario[(a)] (the pair of black lines, which thus show the range of the second coolest to second warmest of the 16 simulations at each year)

– 19 simulations from 8 GCMs following the 'SRES A2' scenario[(b)] (the pink and purple shading, second coolest to second warmest simulations)

– 22 simulations from 8 GCMs following the 'SRES B1' scenario[(c)] (the blue and purple shading, the second coolest to second warmest simulations)

– 5 simulations from the MRI-CGCM2.3.2 GCM[(d)] following the 'SRES A2' scenario (the pair of red lines, coolest to warmest simulations)

All scenarios are identical until 2000, afterwards differing in their greenhouse gas and sulphate aerosol emissions, but assuming constant year 2000 values of all other external forcings. The multiple simulations from each model differ from each other in the weather assumed to be occurring on the first day of the simulation period

(a) the scenario in which emissions are held constant at year 2000 values
(b) the 'business-as-usual' scenario with the highest emissions
(c) the 'business-as-usual' scenario with the lowest emissions
(d) a model developed by the Japanese Meteorological Research Institute

In fact, the estimates given in these reports and elsewhere are not predictions but rather 'projections': they depend explicitly on a hypothetical scenario of future external forcing. These scenarios fall into one of two classes. The first class consists of the 'business-as-usual' scenarios, with greenhouse gas and sulphate aerosol concentrations in the atmosphere evolving under the assumption of no policy interventions (17). Differences between these scenarios arise from different assumptions in the global transfer of clean technologies and in the degree of environmental concern of the general population. The other class of scenarios assumes policy intervention. Unfortunately, only the 'commitment' scenario, wherein post-2000 values of all forcings are held constant at year 2000 values, has been simulated in a large number of models so far. The simulated globally and annually averaged surface temperature response to these forcings is shown in Fig. 2, with the simulated precipitation response shown in Fig. 3.

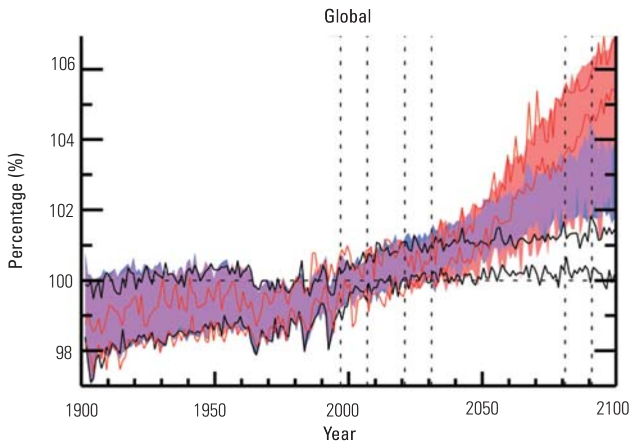

Fig. 3

Time series of annually and globally averaged precipitation from climate model simulations following various emissions scenarios, as a percentage of the 1997-2006 average

A brief explanation of each scenario can be found in the legend of Fig 2.

The ranges plotted indicate the very approximate 5th-95th percentile range of:

– 16 simulations from 8 general circulation models (GCMs) following the 'commitment' scenario (the pair of black lines, which thus show the range of the second coolest to second warmest of the 16 simulations at each year)

– 19 simulations from 8 GCMs following the 'SRES A2' scenario (the pink and purple shading, second coolest to second warmest simulations)

– 22 simulations from 8 GCMs following the 'SRES B1' scenario (the blue and purple shading, second coolest to second warmest simulations)

– 5 simulations from the MRI-CGCM2.3.2 GCM following the 'SRES A2' scenario (the pair of red lines, coolest to warmest simulations)

All scenarios are identical until 2000, afterwards differing in their greenhouse gas and sulphate aerosol emissions, but assuming constant year 2000 values of all other external forcings

The business-as-usual scenarios cannot be considered actual predictions because the whole point of the global mitigation policy discussion is to avoid such a future. Similarly, the commitment scenario is already at odds with recent increases in greenhouse gas emissions. Notably, all such scenarios assume that other external forcings will be constant in the future. Thus, even if greenhouse gas and sulphate emissions followed one of these scenarios, the predicted climate change would probably be overestimated, and its uncertainty underestimated, because of the exclusion of the cooling effect of any future explosive volcanic eruptions which have the potential to substantially cool individual years and perhaps even a decade as a whole. Furthermore, other anthropogenic effects on the climate system are likely to change substantially; for instance, deforestation in the tropics could substantially affect local, and even global, future climate. These omissions are the reason why simulations of the future always look smoother than simulations of the past (Fig. 2).

So what can be said amongst all of this uncertainty? Despite all of the above caveats, the effect of anthropogenic greenhouse gases will become the overwhelmingly dominant factor affecting global, and probably even local, climate change over the coming century. This means that even though details are uncertain, the basic story is fairly robust. Thus, while estimates of future change and its uncertainty may be provided in quantitative form, these numbers should be interpreted qualitatively.

The 2020s

At the first level, the world is going to warm. This is not simply because of our current emissions but because the climate system is still slowly responding to the greenhouse gases already in the atmosphere (16), as seen in Fig. 2 where the world continues warming even under the commitment scenario. Over the next couple of decades, recent trends in greenhouse gas and sulphate emissions are expected to continue (17). For these reasons, and GCM studies indicate that we are not close to any surprises, projections of how the 2020s will differ from the past decade seem pretty robust, meaning they are effectively predictions (possible explosive volcanic eruptions notwithstanding).

Figure 2 highlights the projected difference in annually and globally averaged surface air temperature between the 2021-2031 decade and the 1997-2006 decade according to simulations from a number of GCMs following the 'SRES A2' and 'SRES B1' forcing scenarios. SRES A2 is the future emissions scenario from the popularly modelled subset of the IPCC SRES (Special Report on Emissions Scenarios) series with the highest future emissions, while SRES B1 is the one with the lowest (17). No matter which of these two business-as-usual scenarios of anthropogenic warming is used, the estimates are pretty much the same for the 2020s. Both project almost all of the 2020 years to be warmer than the warmest of the 1997-2006 years. In fact, even simulations following the so-called 'commitment' scenario (the pair of black lines in Fig. 2), with greenhouse gas concentrations held at year 2000 values, overlap in the 2020s with the simulations from the two SRES scenarios and project that about nine years from the 2020s will be warmer than the 1997-2006 average.

Furthermore, the choice of GCM does not matter either: the spread of SRES A2 simulations from the MRI-CGCM2.3.2a model (a model built by the Japanese Meteorological Research Institute and which is highlighted here simply because more simulations have been generated with it), for instance, fully covers half the spread of the larger collection of SRES A2 simulations (the pair of red lines in Fig. 2). The differences between each of these simulations with the MRI-CGCM2.3.2a model arise only because of different guesses of the weather on the first day of the simulation period. This implies that most of the uncertainty in the estimated warming does not come from uncertainty in our future emissions or model formulations, but in fact simply indicates the natural internally generated variability, or 'noise', of the climate system. Figure 2 is thus showing how the weather will differ between the two decades, not how the climate will differ: we are almost certain about how the climate will change, but not how the weather will.

Projected precipitation changes are shown in Fig. 3. Not surprisingly, changes in precipitation are harder to distinguish against the background noise than are changes in temperature. This is both because precipitation is generally noisier and because it responds less directly to the increases in greenhouse gas concentrations. Because precipitation is noisier, the conclusions above for temperature are even stronger for precipitation: the simulated responses to the various scenarios and models are practically indistinguishable from one another.

If this is basically a weather forecasting problem, then it may seem more useful to be running the GCMs from today's actual meteorological state, rather than some arbitrary possible state (as has been done with the simulations used here). The possibility of including this initial condition information is starting to be examined (19). There remain a number of issues to be resolved with this approach though, such as how to evaluate the accuracy of the forecast from the relatively short historical record and how to deal with a common tendency of GCMs to drift away from real world conditions. Consequently, current 'decadal forecasts' are in fact probably less accurate than the simple climate change projections presented here.

The 2080s

The problems differ somewhat for the 2080s (4). For one thing, the course of emissions scenarios matters, with no overlap for the 2080s between the simulations following the two SRES scenarios in Fig. 2, for instance. The simulations following the commitment scenario differ even more in that they show no further warming above that already experienced in the 2020s, whereas the SRES scenarios have warmed by 1°C since the 2020s. This means that we really do not know what the 2080s will be like, because the climate of that decade will depend enormously on what social, economic, and political decisions are made in the interim.

The choice of model also becomes important, with the MRI-CGCM2.3.2a SRES A2 simulations now covering only a small portion of the spread of the larger collection of SRES A2 simulations. This arises because the differences in parametrisations of sub-grid scale processes in the various models have become magnified by the large amount of warming. A model with a large sea ice retreat feedback, for instance, is now able to show off that large sea ice retreat. GCMs seem to agree quite strongly on the large-scale pattern of climate change though, with the differences primarily in the amplitude of that change. Consequently, we can compare the observed warming to a model's response to the past external forcings and use that comparison to calibrate our estimate of future warming. When this is done, the models come into closer agreement in the 2080s (23, 24).

These properties are also apparent in the simulated precipitation response shown in Fig. 3, even though precipitation is inherently more variable. In particular, the ways that models parametrise precipitation and other related unresolved processes, such as cloud formation, become quite important. In fact, the difference in spread between the SRES A2 scenario simulations and the SRES B1 scenario simulations arises mainly because of the MRI-CGCM2.3.2a model, which is quite sensitive to the difference in scenario, with the other models not being so sensitive to the choice of scenario. Because the precipitation response depends on the heuristic parametrisations rather than brute modelling of the underlying physics, our confidence in the simulated precipitation response to greenhouse gas increases is much lower than our confidence in the simulated temperature responses.

Regional climate change

As in the previous section, the reader is referred to the IPCC assessment for a comprehensive review of regional predictions of future climate (3), with summaries in the 2007 IPCC report (7) and Solomon *et al.* (21). Not surprisingly, the uncertainties become greater at the smaller regional scales, but the general properties of the global climate change still hold.

Figure 4 shows the global pattern of estimated warming of the 2020s from the 1997-2006 average. Unlike the annually averaged data shown in Fig. 2, the data shown in Fig. 4 are decadally averaged for simplicity and in order to highlight features. The maps are generated from 33 simulations from 10 GCMs following the SRES A1B

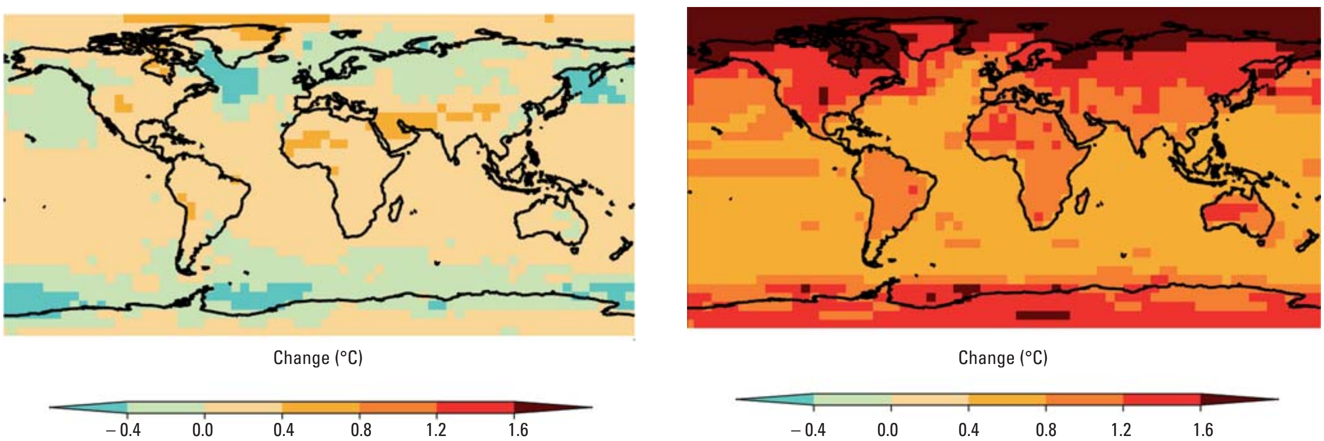

Fig. 4
Maps of the decadally averaged surface temperature difference between the 2021-2030 decade and the 1997-2006 decade
The left panel shows the very approximate 5th percentile at each grid cell from 33 simulations from 10 general circulation models following the SRES A1B scenario[(a)]. For each 5° latitude by 5° longitude grid cell, the warming from the simulation closest to the 5th percentile of warming (the third coolest temperature difference) is shown. The right panel shows the approximate 95th percentile of warming (the third warmest temperature differences)

(a) a 'business-as-usual' scenario between SRES A2 (with the highest emissions) and SRES B1 (with the lowest emissions) scenario, a business-as-usual scenario between SRES A2 and SRES B1. The left-hand map shows the smallest amount of warming (or largest amount of cooling) that we may reasonably expect to experience at any one location on the 5° latitude by 5° longitude grid (~5% chance of being lower), while the right-hand map shows the largest amount of warming we may reasonably expect to experience (~5% chance of being higher) at any one location. Each map is showing the 'reasonable' (i.e. ~5% chance) extreme cooling/warming at each location; it is much less likely than 5% that all locations on the map would experience such an extreme cooling/warming in any given simulation (or in the real world realisation that will happen), because some areas may experience greater warming than expected and others less than expected. Warming is not guaranteed at any one location, although in all locations the odds are high that warming will occur. The greatest amount of warming is expected (and has been observed) over land and over high latitude regions; however, these locations are also the ones with the highest uncertainty about the future warming. The changes projected for the 2080s (Fig. 5) are similar but considerably more significant, with it being very unlikely that any particular location will not experience a noticeable warming.

Projected changes in decadally averaged precipitation in the 2020s with respect to the 1997-2006 decade are shown in Fig. 6, as percentages of the 1997-2006 average. No consistent features are visible in the maps, both because precipitation is much more variable than temperature and because it responds much more indirectly to increases in greenhouse gas concentrations than does temperature. The maps only really indicate that the largest potential changes and the highest uncertainties coincide with areas with low base precipitation amounts, particularly deserts and polar regions. The projected changes for the 2080s are still quite noisy, although a few distinctive features may be emerging (Fig. 7). The main feature is that the polar regions will get more precipitation. This will mainly arise because the retreat of the sea ice and lake ice will allow surface waters to evaporate more directly into the polar air. There is also some suggestion that some subtropical areas will become drier.

Everything that we have discussed so far has considered annual (or decadal) average quantities; however, at the regional scale, projected changes may depend on the season. For instance, the higher warming at high latitudes is expected to be strongest during the winter and early spring seasons. Furthermore, changes in the frequency or intensity of 'extreme' weather events may not directly follow changes in the average. One reason for this is demonstrated in Fig. 8. If we say that daily August temperatures in the recent past have followed the blue probability distribution, then the red probability distribution will correspond to some period in the future that is on average 0.5°C warmer. We will call 'extremely hot' those days that are more than 1.5°C warmer than the average of the recent past. Less than 7% of days in the recent past were extremely hot, but in the future period more than 15% will be so. The probability of an extremely hot day will have increased by more than a factor of two, even with just a half standard deviation shift in the average temperature. The converse would of course follow for extremely cold days.

Changes in the frequency of extreme weather events may change for more physical reasons too. For instance, if

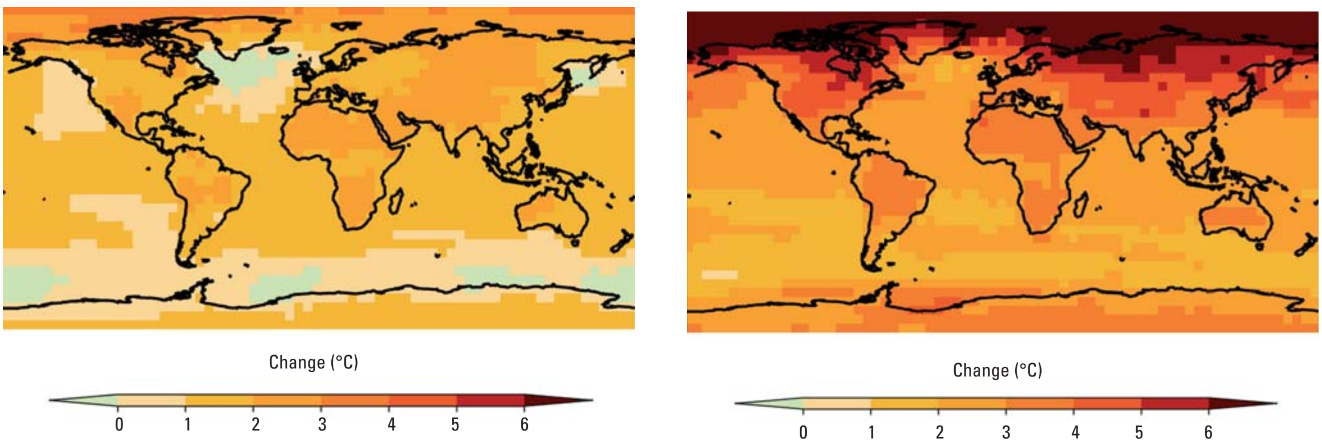

Fig. 5

Maps of the decadally averaged surface temperature difference between the 2081-2090 decade and the 1997-2006 decade

The left panel shows the very approximate 5th percentile at each grid cell from 33 simulations from 10 general circulation models following the SRES A1B scenario. For each 5° latitude by 5° longitude grid cell, the warming from the simulation closest to the 5th percentile of warming (the third coolest temperature difference) is shown. The right panel shows the approximate 95th percentile of warming (the third warmest temperature differences)

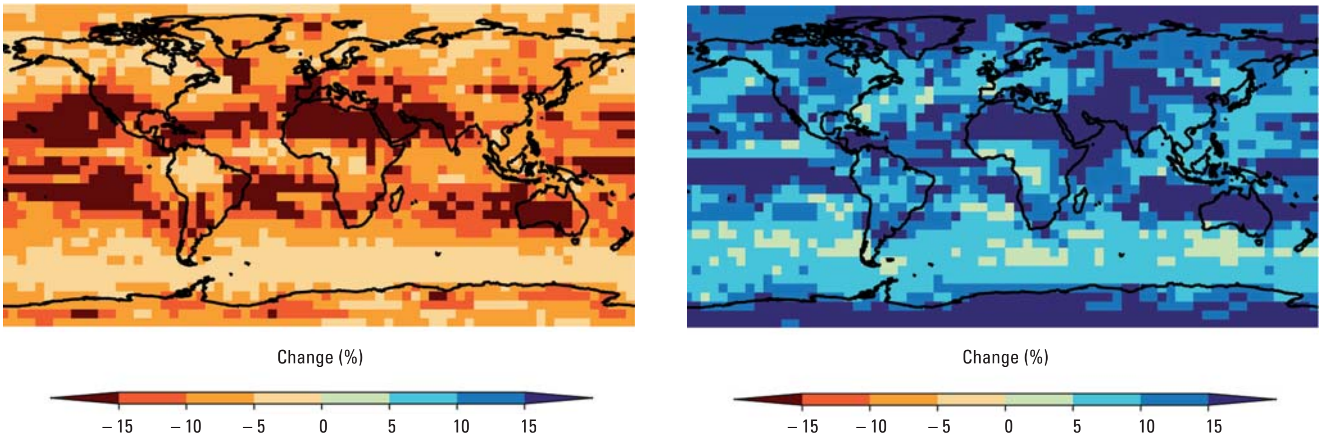

Fig. 6
Maps of the decadally averaged precipitation difference between the 2021-2030 decade and the 1997-2006 decade, as percentages of the 1997-2006 average
The left panel shows the very approximate 5th percentile at each grid cell from 33 simulations from 10 general circulation models following the SRES A1B scenario. For each 5° latitude by 5° longitude grid cell, the precipitation change from the simulation closest to the 5th percentile of increasing precipitation (the third driest precipitation difference) is shown. The right panel shows the approximate 95th percentile of increasing precipitation (the third wettest precipitation differences)

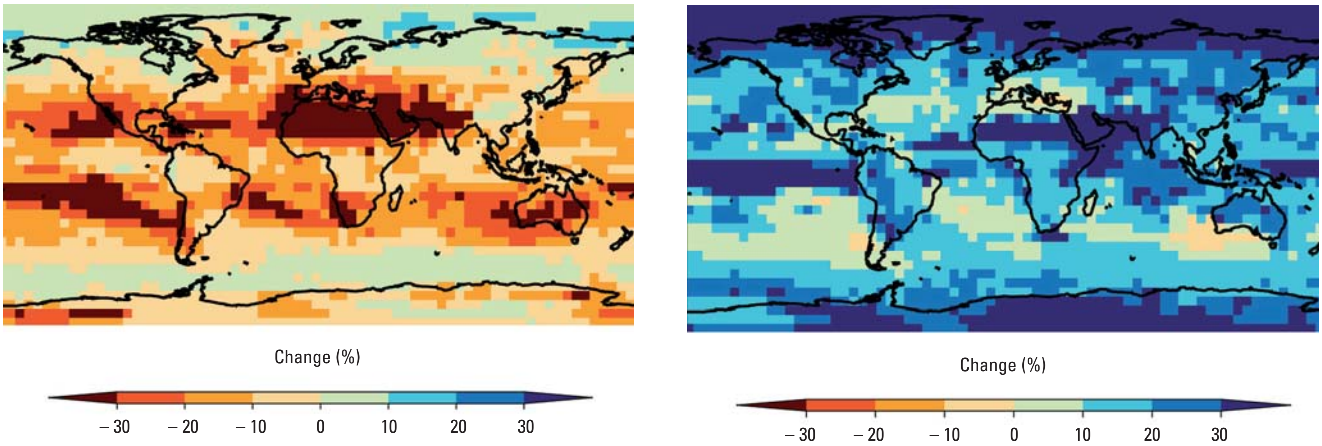

Fig. 7
Maps of the decadally averaged precipitation difference between the 2081-2090 decade and the 1997-2006 decade, as percentages of the 1997-2006 average
The left panel shows the very approximate 5th percentile at each grid cell from 33 simulations from 10 general circulation models following the SRES A1B scenario. For each 5° latitude by 5° longitude grid cell, the precipitation change from the simulation closest to the 5th percentile of increasing precipitation (the third driest precipitation difference) is shown. The right panel shows the approximate 95th percentile of increasing precipitation (the third wettest precipitation differences)

rainfall decreases over a given area, there may be no obvious effect on the average temperature; heatwaves, on the other hand, may become much more common, because of a lack of moisture to cool the ground through evaporation during more frequent dry periods. As for rainfall, projected changes in the frequency of extreme hourly and daily events are in fact expected to be unrelated to changes in the average rainfall (1). The average rainfall amount depends mostly on the vertical temperature gradient of the atmosphere, in other words on how quickly the top of the atmosphere can radiate energy into space, which will change only slightly with increased carbon dioxide concentrations. On the other hand, short extreme rainfall events depend on how much water the air can hold, which increases exponentially with temperature. So in a future warmer world, short extreme rainfall events should become much stronger and more frequent, possibly even in areas that become drier on average.

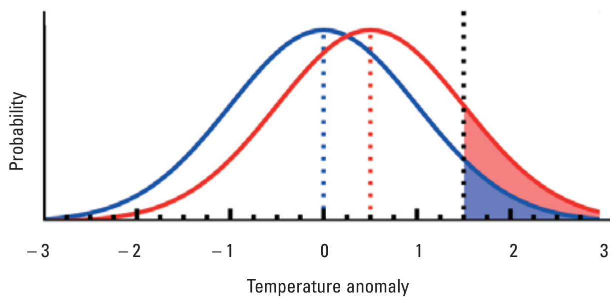

Fig. 8
Demonstration of how changes in the frequency of extreme weather events can change markedly with only a minor change in the average
The solid blue curve represents, say, the probability distribution of daily temperatures in August in the recent past, while the solid red curve corresponds to some future in which the average temperature (denoted by the coloured dotted lines) has increased by 0.5°C. The frequencies of exceedance of a threshold for extremely hot days (the dotted black line) are indicated by the shading

Implications for disease impact studies

What does all this mean for animal health? Basically, any estimates of the future effect of weather on animal health will be uncertain because the weather forecast is uncertain (and the inherent uncertainties in animal epidemiology make the task even more complicated). All is not lost, however, as we can say reasonably robust things about the weather over the next few decades. Nevertheless, in the longer term, we are not nearly so sure about what will happen, not only because the extrapolations that we are forcing the climate models to give us become more suspect, but also because the unknown ways in which our greenhouse gas emissions will change in the intervening years become very important.

The gap between the spatial resolution of climate model output and the spatial scale of concern in animal health assessments remains a major problem. On a global average it may not matter much, but health assessments are generally of much more local interest. A further issue is that the microclimate experienced by any particular animal or disease agent may not be identical to the overall climate of the area. For instance, the climate state experienced in a forested area depends crucially on whether one is above or below the forest canopy. Climate models are gradually including more sophisticated representations of the land surface, such that many models today are starting to include representations of the vegetative response to weather. While still new, and thus with some important shortcomings, these additions have produced noticeable improvements in the climate produced by the models over some regions. Nevertheless, the biggest determinant of vegetative change over the coming decades will probably not be a response to climate change, but rather the effects of urbanisation and deforestation. Land use change is yet to be included in future forcing scenarios. In any case, the local effects of urbanisation or deforestation can be so draconian as to make the climate change issue secondary.

The spatial resolution of climate models is also an issue in the oceans. In fact, the problem may be even more acute there. The supply of nutrients from water coming up to the ocean surface is the primary control of life in the open ocean. Away from the equator this upwelling occurs mostly within eddies (swirling masses of water typically tens of kilometres across) much smaller than the resolution of the ocean component of the model. The ability of models to adequately resolve the vertical structure of the crucial thermocline level of the ocean (the depth at which the water temperature begins to drop rapidly) is questionable at the moment, so if and how it may change is an unresolved question.

Like any tool, climate models have their limits. While many of these limits are being pushed back with the rapid progress in computing power, some will remain indefinitely. Nevertheless, if interpreted properly, climate models can be a powerful instrument in determining how future weather will differ from today's weather. While limited as well, the use of regional climate models and empirical down-scaling, amongst other techniques, allow climate model predictions to be taken further than otherwise possible. As long as the limitations are recognised, and results interpreted qualitatively rather than quantitatively when necessary, such models and techniques can be powerful tools.

Acknowledgements

The author wishes to thank Ruth Cerezo-Mota and Dana Šumilo for comments on the manuscript. The author acknowledges the international modelling groups for providing their data for analysis, the Program for Climate Model Diagnosis and Intercomparison (PCMDI) for collecting and archiving the model data, the JSC/CLIVAR Working Group on Coupled Modelling (WGCM) and their Coupled Model Intercomparison Project (CMIP) and Climate Simulation Panel for organising the model data analysis activity, and the IPCC WG1 TSU for technical support. The IPCC Data Archive at Lawrence Livermore National Laboratory is supported by the Office of Science, U.S. Department of Energy. The author was funded by a Tyndall Postdoctoral Fellowship during the writing of this review.

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Le changement climatique attendu pour les prochaines années et ses conséquences sur les études d'impact sanitaire

D.A. Stone

Résumé

L'auteur fait le point sur les prédictions que les spécialistes des modèles climatologiques sont à même de produire concernant l'évolution future du climat. En effet, s'il est possible d'anticiper le changement climatique des prochaines décennies au moyen de modèles suffisamment robustes, les prédictions visant un futur plus éloigné sont affectées par les incertitudes liées à la structure du modèle climatologique et à l'évolution encore inconnue des émissions de gaz à effet de serre. Certains traits caractéristiques sont perceptibles au niveau régional ; néanmoins, à l'heure actuelle, les seules interprétations significatives de ces traits correspondent à des échelles spatiales trop vastes pour permettre d'anticiper avec justesse les effets sur la santé animale du changement climatique. En conséquence, les prédictions réalisées actuellement sur le changement climatique sont plutôt des indications que des descriptions exactes de l'évolution future.

Mots-clés

Changement climatique – Climat – Météorologie – Modèle – Prédiction.

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Cambios del clima previstos para los años venideros y su repercusión en el estudio de las consecuencias de las enfermedades

D.A. Stone

Resumen

El autor hace balance de la capacidad actual de los círculos científicos que trabajan con modelos climáticos para formular predicciones relativas a la futura evolución del clima. Aunque las predicciones para los próximos decenios son razonablemente sólidas, la anticipación referida a periodos más largos de tiempo depende de inciertos factores ligados a la estructura de los modelos climáticos y a la incógnita de cómo evolucionarán las emisiones de gases de efecto invernadero. En el plano regional destacan una serie de características, aunque ahora mismo sólo es posible interpretarlas cabalmente a una escala espacial bastante mayor de lo requerido para hacer previsiones fiables de la futura influencia del cambio climático en la salud animal. El corolario de todo ello es que ahora mismo no cabe tener por exactas, sino sólo meramente indicativas, las predicciones ligadas al cambio climático.

Palabras clave

Cambio climático – Clima – Elaboración de modelos – Meteorología – Predicción.

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