Global warming: the rest of the story

Is the greenhouse effect something we should fear, or is it a figment of the media's overheated imagination? Gerd R. Weber explains the effect of trace-gases in the atmosphere in Part 1 of a series.

We are pleased to present excerpts from a forthcoming book by German meteorologist Gerd R. Weber, Global Warming: The Rest of the Story *(Böttiger Verlags-GmbH, Wiesbaden, Germany). The book has already appeared in German under the title* Treibhauseffekt: Klimakatastrophe oder Medienpsychose?

In his Introduction, Weber describes his purpose as being to "provide the reader with the current state of knowledge on all the issues related to the greenhouseeffect and the possible future direction of the climate, and with an action plan to cope with a possible climate change.

"We will take a journey through the wonderland of science. We will first look at the greenhouse effect, and examine its meaning and importance for life on Earth; second we will discuss why it is increasing, and how this may be affecting the climate. Then we will look at the climate itself, what it is, and what might cause it to change in general, the way it has evolved through the centuries, and we will determine whether we can already see some signs of the greenhouse effect. We will also try to assess how life on Earth will change if the climate does change the way some people expect it to. And we will, of course, probe into the question of whether climate will really *change the way it is expected."*

This series will be slightly abridged from Chapters 3 and 4 of Weber's own English translation. For reasons of space, we are not able to reproduce all of the graphics, and for clarity, they are numbered consecutively as they appear here.

On the threshold to climate modeling

So far in our quest to examine the scientific basis of the greenhouse effect and the predictions of future global warming, we have achieved the following:

1) We have found out what the greenhouse effect is—both natural and man-made;

2) found out which trace-gases and human activities contribute to it; and

3) with a lot of if's, did some crystal-ball gazing and attempted to find out what the future concentration of those gases might be.

Our next step will be to assess in which way *the climate* might change *if* the trace-gases do increase in the suggested manner. The climatic changes we will be talking about are "what if" scenarios. In other words, we will be considering changes which might occur *if* trace-gases increase in the manner and to the extent assumed by the climate-model predictions.

This is where the infamous "if present trends continue" enters the game once again.

And we also draw closer to the central issues of the debate, i.e., climate predictions. No one would have become upset about trace-gas increases as such, which is all we have discussed so far, if it had not been for those dire climate predictions which stirred up a storm. Consequently, one of our major endeavors will be to examine those climate predictions: Only if there is reason to believe that they are correct, is the concern about increases of trace-gases justified.

Before we actually embark on a journey through the wonderland of climate prediction, there is still one job left to do from the preceding chapter: We will examine what happens to CO_2 once it has been injected into the atmosphere by one or another carbon-burning process.

The carbon cycle: Welcome to life on Earth

Many people may actually be very surprised to hear that carbon dioxide, which sounds so much like the air pollutant "sulfur dioxide" or "nitrogen dioxide" is not a pollutant at all. Instead, it is a substance without which life on Earth as we know it would not be possible. Carbon dioxide, and more generally, carbon, is continuously cycled through nature and it is reflected in every facet of life on Earth. In fact, it is the very building block of life. No plant life, no animal life, including human life, would be possible were it not for carbon dioxide. As you are sitting here reading this book, you breathe, and as you breathe you exhale carbon dioxide, which your body produces while oxidizing carbon compounds contained in the food you ate earlier in the day. And while human beings emit—breathe out—CO_2 just as a motor vehicle does when it burns gasoline—nature (trees, flowers, corn fields) takes it in through a process called photosynthesis, in which plants breathe in CO_2, take the carbon out of the carbon dioxide, use it to build stems, twigs, branches, leaves, blossoms; in turn they emit oxygen into the environment and therefore give it back to us. But human beings, in turn, use those plants—tomatoes, apples, watermelons—they eat them and burn the carbon contained in them during the metabolic process—breathing out CO_2.

This is a very simple, but nevertheless illustrative example of a carbon sub-cycle. There are many more of those cycles which link up to what is called the "global carbon cycle."

Let us pause momentarily and consider this cycle one more time. If the carbon dioxide we emit by breathing, driving to work, and heating our apartments is taken up by plants, in fact is necessary for them to thrive, how can it be that carbon dioxide got such a bad reputation recently? If it's that good for the biosphere, shouldn't we be putting *more* of it into the atmosphere to make plants grow better? Moreover, would that not possibly solve some of the envisioned future food production problems in some parts of the world? As we shall see in a little while, there is—as one of the biggest ironies in the trace-gas/climatic change debate—an almost unconditional yes to those questions.

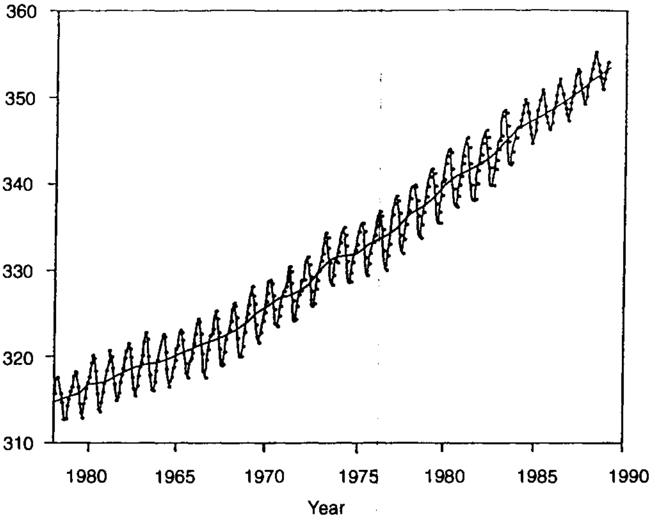
But the problem now at hand is that more CO_2 enters the atmosphere than our biosphere can handle at the present time. In addition, the biosphere is being continuously destroyed by deforestation and changing land use patterns, particularly in the tropics, thereby reducing the base which can swallow excess CO_2. On the other hand, it has been suggested that the biosphere in mid-latitudes of the Northern Hemisphere has been expanding in recent decades—swallowing increasing amounts of CO_2.

Moreover, what remains of the biosphere does respond to what is called CO_2 fertilization, i.e., the increased production of biomass through increased levels of CO_2 in the atmosphere. Some scientists think that this process, which is easy to demonstrate in experimental set-ups, has in fact already occurred in nature, and can be deduced from the increasing amplitude in the wiggles in the curve in **Figure 1,** the curve showing the atmospheric carbon dioxide increase: Whenever the biosphere takes a deeper breath, those wiggles grow larger.

FIGURE 1

Historic CO_2 concentrations observed at Mauna Loa, Hawaii

(parts per million by volume)



Source: *Global Warming, The Rest of the Story;* U.S. Department of Energy, Report DOE/FE-0164.

However, much of the carbon taken up by plant tissue and fixed to them in summer, is re-emitted into the atmosphere when leaves fall off a tree, or when herbacious plants die and begin to rot. Rotting means bacterial decay in which CO_2 is produced and recycled into the atmosphere.

Some of the carbon is incorporated into the woody tissue of trees and may stay there, not only for years and decades, but for centuries and millennia, because that is how long some trees live. Therefore, trees and other woody plants provide what is called a "sink" in the carbon cycle as opposed to sources, such as burning of fossil fuels and deforestation, microbial decay of leaves and other organic matter.

But the relationship of the sink of CO_2 fixation to woody tissues is at present neither large enough to completely counterbalance the source of fossil fuel-derived CO_2, nor to even explain why only half of it appears in the atmosphere. But if the biosphere does not provide a sink large enough to account for the "missing carbon"—on the contrary, at present it is a source, and probably has been for some decades—where does the carbon go?

Enter the oceans. They cover nearly three-fourths of the Earth, and we may sometimes have the impression that it hardly matters what happens on land, in terms of the carbon cycle and many other geological and chemical cycles, but also with respect to climate, as we shall see.

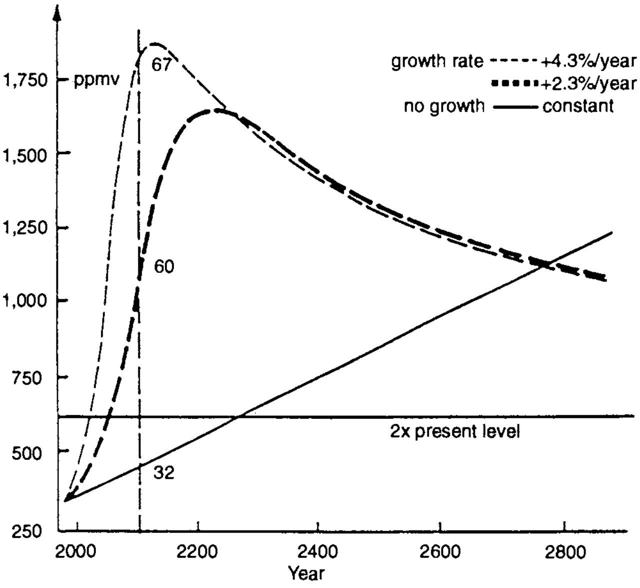
The oceans play a key role in the global carbon cycle. They take up CO_2, put it into solution and make it available to a number of physical, chemical, and biological processes.

Physically, carbon may be transported horizontally and vertically by ocean currents. We know from observations and modeling studies that CO_2 is primarily taken up by the

FIGURE 2

Growth of atmospheric CO_2 concentration as a function of the emissions growth rate

(in parts per million)



Source: *Global Warming, the Rest of the Story,* Maier-Reimer and Hasselmann, Climate Dynamics, 1987

oceans at high latitudes and transported downwards and toward the equator. Chemically, it interacts with calcium carbonate, the material seashells are made of. Biologically, it is used to form plankton, which eventually sinks to the sea floor, thereby removing carbon from the ocean surface. All these processes combined remove carbon from the atmosphere and provide the biggest sink for carbon. But it still is not enough to balance the carbon budget, because, as we know, atmospheric carbon is increasing.

Much the same as in the biosphere, but on a larger scale, the ability of the oceans to curb the increase of atmospheric carbon depends on the rate—or speed—at which it is injected into the atmosphere and made available to the oceans. If the capability of the oceans to swallow CO_2 is less than the rate at which it is emitted into the atmosphere, the oceans cannot take it up and atmospheric concentrations will increase at a rate dependent on the emission rate in a way illustrated in **Figure 2.**

Figure 2 presents results from model calculations incorporating physical and chemical, but no biological processes in the oceans. The interesting aspect of Figure 2 is that the rate of atmospheric increase slows dramatically as the input rate moves from 2% to 0%, i.e., constant emissions, but changes only very little as we move from a constant rate to a negative growth rate, in other words a reduced emissions scenario.

Now, we recall from the previous chapter that our estimated emissions growth rate for the next 50 years was between 1-1.5%, and we are therefore right in the middle of that territory of Figure 2 where large variations in the atmospheric concentration can be expected as a function of the input rate. Therefore, the future atmospheric CO_2 concentration will very critically depend on whether emissions growth is at, say, 1 or 2%.

If we then apply our 1-1.5% scenario to Figure 2, a doubling of CO_2 would not occur in the foreseeable future, but sometime in the early 22nd century. In a constant emission (no growth scenario), doubling would occur around the year 2300 and in a 2.3% scenario, near the middle of next century, as many assume.

Interestingly, though, the 1-1.5% scenario would then approximately translate into a 0.5% atmospheric growth rate—approximately a continuation of "present trends"—present meaning the last 20 years. Referring once again to the IPCC [Intergovernmental Panel on Climate Change] scenarios, we would not be somewhere in the middle between scenarios "A" ["Business-as-Usual"] and "B" after 50 years, but closer to "B" than envisioned before (see **Figure 3**). It should be recalled, however, that the ocean's biology, which may further dampen and slow down, is not yet included in these calculations. Likewise, the terrestrial biosphere is also not accounted for—which might act as a considerable sink. We may therefore conclude that even though CO_2 emissions from fossil fuel-burning will continue to grow, the likelihood of a rapid and dramatic CO_2 buildup is smaller than previously thought, particularly if biomass burning has been a relatively large source in the past and will be curbed in the future: a conclusion which has obvious ramifications concerning the time frame and the magnitude of a possible greenhouse warming. We recall that the magnitude and time frame of a greenhouse warming had to be altered once before by the less-than-expected rate of increase of the second most important greenhouse gases, the CFCs. Recalling the IPCC scenarios, where we would now be closer to "B" on CO_2, between "B" and "C, D" on the CFCs and on "A" with methane plus a small contribution from ozone, we might expect to end up closer to "B" than to "A" as a rough estimate.

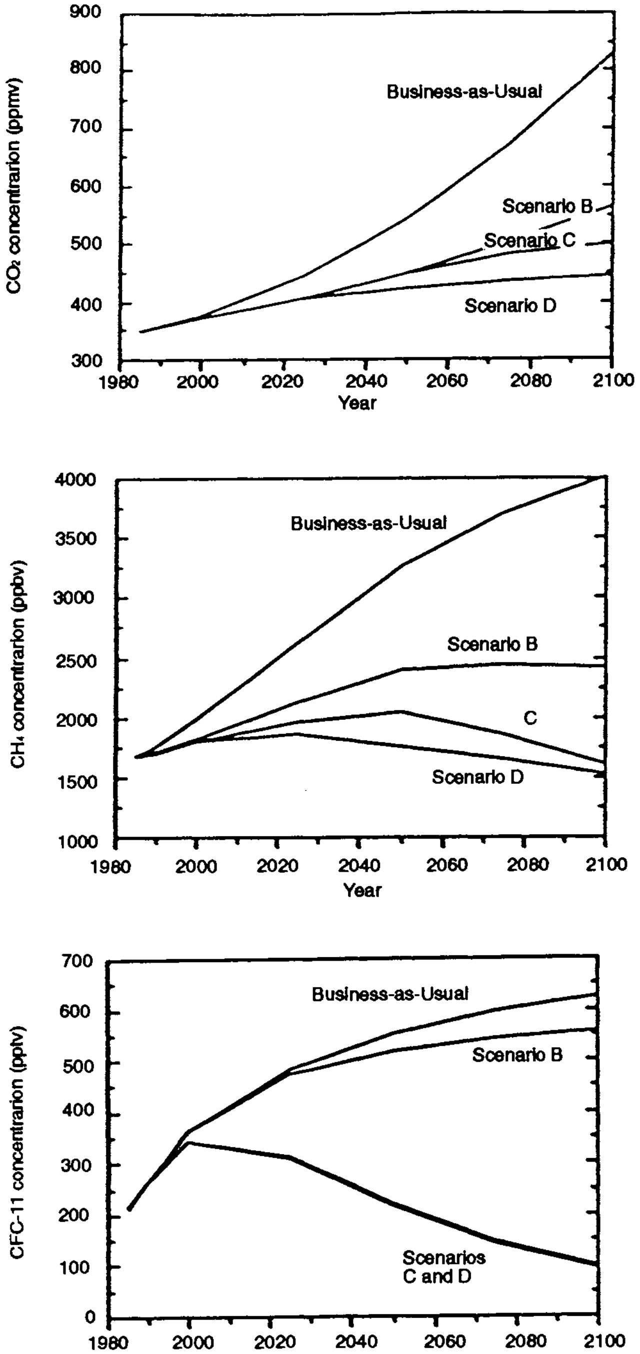
This is because CO_2 will remain the predominant greenhouse gas and large increases of methane will be balanced somewhat by smaller increases of the CFCs, which are potentially more powerful greenhouse gases.

We may then ask again: Could it be that all those horrific impacts on climate, which we still have to assess, if they really occur at all, would not occur as soon as a lot of people claim, but much further down the line, possibly giving us much more time to either combat them or adjust to them, and thereby take the tone of urgency out of the voiced concerns? According to everything we have heard so far, the answer can only be yes.

Let us now return to CO_2 and analyze one aspect of an atmospheric carbon dioxide increase which is frequently overlooked altogether or only dealt with in passing, but which we have briefly touched on a little earlier, namely the impact of the biosphere.

FIGURE 3

Projected atmospheric concentrations of CO_2, CH_4, and CFC-11 resulting from the four IPCC emissions scenarios



Source: *Global Warming, the Rest of the Story*, Intergovernmental Panel on Climate Change, 1990.

CO_2 does assume a special role indeed, since, in contrast to all other trace-gases emitted from fossil fuel-burning, it is *not* a pollutant with potential detrimental effects on the biosphere such as SO_2 or acid rain, or photochemical oxidants, but a gas essential and beneficial to the thriving of our biosphere.

Therefore, by emitting CO_2 into the environment, man is *not* harming it, but rather benefitting it, certainly over any CO_2 range that might possible occur as a result of continuing fossil fuel-burning.

This is a fact which many people have a hard time grappling with, especially since it has been ingrained in people's minds that man's actions could only harm the environment. This one-sided doomsday view of the world is particularly prevalent among those who, because of their ideological position, maintain that any change, as long as it is man-induced, is bad per se and ought to be resisted. Surely this is a philosophical point and has nothing whatsoever to do with the relevant science. Since we are concerned with the *scientific* basis of the greenhouse effect and matters related to it, we will not dwell on those philosophical aspects, but rather return to science and present an image of the biosphere—the way it may evolve under increasing CO_2 concentrations.

There are in fact a large number of studies which have attempted to evaluate the possible impact of an enhanced CO_2 level on a variety of plants, both natural and cultivated.

The general conclusion of those studies is overwhelmingly positive on CO_2 and may be summarized as follows:

Increasing CO_2 levels lead to increases in photosynthesis, plant weight, plant branch numbers, fruit numbers, fruit size, plant tolerance of atmospheric pollution, and plant water efficiency.

While the first factors simply reflect CO_2's role as a fertilizer, the last two factors are related to the way a plant operates. It breathes through tiny openings in its leaves, called the stomatae, which may open or close depending on the environmental conditions. Increased CO_2 acts as an antitranspirant, causing the stomata openings to close partly and take in less air pollutants and lose less water through transpiration, factors which may be important under drier, but CO_2-enriched conditions.

Those positive effects may not be as large though, if other nutrients such as nitrogen or phosphorous are in insufficient supply. But curiously enough, nitrogen has not been a limiting factor in recent decades—at least not in the more industrialized regions of the Northern Hemisphere. This is because nitrogen emissions are another by-product of fossil fuel burning; and even though nitrogen emissions are considered air pollutants, they do have a fertilizing effect on plants, and therefore add to the general stimulus given to plants by the increasing level of CO_2.

Some scientists claim that weeds may grow better under a high CO_2 scenario, thereby nullifying—at least partly—the expected positive impact on plant growth. The final vote on this has not yet been cast, but as far as trees are concerned, there is growing evidence that they tend to reap a particularly rich CO_2 bonus, since they accumulate carbon and grow bigger year after year—which weeds do not do, since they are mostly annuals.

Furthermore, when the additional impact of higher temperatures is taken into account, which is expected to occur as a result of an increase in the greenhouse effect, it is sometimes claimed that plant diseases may increase and adversely affect any potential gain from a CO_2-enriched atmosphere.

Here another factor comes on stage, namely the impact of higher temperatures on plant growth. We are not yet in a position to determine exactly what higher temperatures may result from the additional greenhouse effect, but . . . a quick glance at existing experimental work that has been conducted to investigate relationships between plant growth at high CO_2 scenarios as a function of temperature . . . [shows] that the higher the temperatures, the higher the growth benefits, at least over the range of temperatures observed on Earth. Remarkably, this is even true for tropical temperatures and it partially reflects the fact that the species variety of the biosphere increases as temperature and moisture increase. This point will be taken up later on, when we assess the possible impact of a climate change on nature, the environment, and human activities.

After examining possible future trace-gas scenarios and various ways carbon dioxide may interact with our natural chemical and biological cycles, and trying to determine how soon a dramatic buildup of greenhouse gas may occur in the atmosphere, we have found out that the very rapid buildup feared not so long ago may not materialize, because we now know that the main greenhouse gases, CO_2 and the CFCs, will in all likelihood grow much slower than was projected so far. In the case of CO_2, this is due to a re-analysis of future energy use scenarios, but also to newer modeling work which explains the absorbing role of the oceans under different CO_2 emission scenarios and, in the case of CFCs, it is the regulatory action taken against them because of their role in stratospheric ozone depletion. This action has the double benefit of also containing the greenhouse effect. Looking again at the IPCC scenarios, our "BaU" ["Business-as-Usual"] scenario would then be lower than theirs.

Welcome to the world of climate modeling

We have now found out how trace-gas concentrations may evolve in the atmosphere, and have therefore laid the groundwork to address the central issue of the current greenhouse debate: What will happen to *climate* if the greenhouse gas buildup continues? Do we already see some effects due to the greenhouse gas buildup which has already taken place?

In this debate, the ability of the climate models to predict future climate changes resulting from increased trace-gas levels takes center stage.

Everything we have heard so far in the media about detrimental climate changes thought to occur from increased trace-gas levels is based on computer model calculations which currently provide the best possible means to estimate future climate changes.

Those computer models were developed over the past few decades to varying degrees of sophistication.

To give you a little bit of detail, there are three major types of models: First, the so-called energy balance models, EBMs, which only consider surface energy fluxes; then second, RCMs, radiative convective models, which also take account of convective air exchange with the atmosphere above a surface point; and finally, the GCMs, general circulation models, which are the ultimate in sophistication and include everything from air currents at various levels in the atmosphere to moisture flow, cloud formation, rain, snow, evaporation, sometimes even the oceans and seasonal and diurnal cycles, in short, the whole works. All of the research we will be considering here, and which is of any relevance to the debate, is based on GCM results. Those models are in fact very similar to the ones used by the Weather Service to compute forecasts for the next weekend, but are extended to include processes which do not have a bearing on tomorrow's weather, but are critically important to climate. Those processes are, of course, the changing composition of the atmosphere and the resultant change in radiative energy, but also exchanges with the surface, such as evaporation.

To make one thing clear, however: No matter how good those models are, they are still only models, incomplete approximations of the multitude of physical, chemical, and even biological processes which take place on Earth, and they are currently far from including *all* processes which may be important to climate. For one thing, we do not even know what they are, and some of the ones we do know about are not yet incorporated into the models because of a variety of computational constraints.

On a forecasting level, we learn to appreciate this every once in a while when a weather forecast, based on computer models, goes bust and instead of sunshine, we have rain on a weekend.

Clearly then, in all types of computer-based weather and climate, there is considerable room for improvement.

Now, a climate "forecast" is achieved by letting the model run not only for the next weekend, but straight out for the next 30 or 50 years.

Let us digress for a moment and define what "climate" is. Climate is the *average* state of the atmosphere and of such parameters as temperature or precipitation, but also the variability and the range of those parameters over an extended period of time. It can be defined for any given location or larger geographical areas. The time period chosen for defining those averages is usually 30 years, but no less than 20 years. When using the term "climate," it is implicitly assumed that climate does not change very much from one 30-year period to the next, in other words, climate is somewhat of a constant. This in itself is an assumption of limited validity, as we will see later on, because climate thus defined is indeed continuously changing at time scales ranging from several decades to centuries and millennia.

A *change* of climate would be a permanent change in a climate parameter from one 30-year period—or an average over a number of such periods—to the following 30-year periods, where the change is of sufficient magnitude to be characterized as such.

This magnitude depends on the natural variability of the parameter. Therefore, if there is a run of seasons or years much shorter than 30 years which is colder or warmer, rainier or drier, than the 30-year average, we do not speak of a climate change yet, but rather of short-term climatic fluctuations.

Consequently, the occurrence of a run of extremely cold winters in the late '70s constituted a climate change as little as the string of extremely hot and dry summers in the '30s, because climate did subsequently return to its long-term norms. The droughts of the '30s and the cold winters of the late '70s are true examples of short-term climatic variations.

The climate models and the greenhouse debate then are not concerned with those short-term climate variations, but rather with long-term, lasting changes which occur on time scales of a number of decades and even centuries.

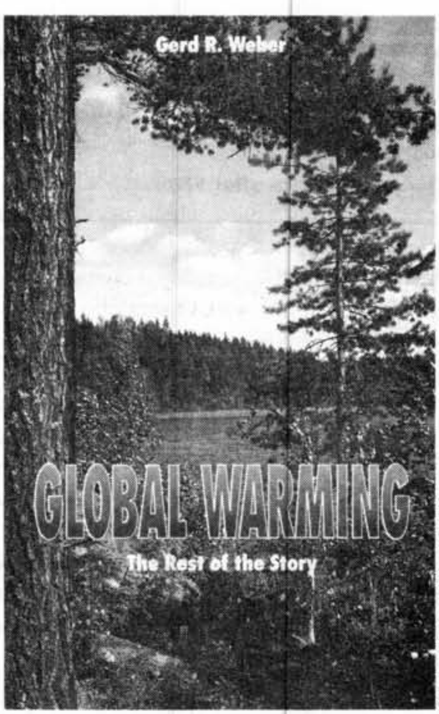
Running a climate model takes a lot of time even on the fastest and best supercomputers, which are very expensive, and there are therefore only a handful of research institutions around the world sufficiently funded and staffed to perform those calculations. Each group of researchers models the atmosphere a little differently, or characterizes the atmospheric physics in a somewhat different manner, and hence the results are different too, especially when they deal with regional detail—and regional means anything under 1,000 miles.

Nonetheless, no matter which model result we consider—after it has been run to simulate about 30 years worth of a doubled CO_2 climate—one basic result is the same from all models: It will get warmer.

Let us now consider what we can epxect, according to those model calculations, if we double the atmospheric CO_2 content—or increase the concentration of all trace-gases to such an extent that it will be the equivalent of a CO_2 doubling.

We will do this by looking at the modeling results of the three largest U.S. institutions involved in climate modeling, namely the Geophysical Fluid Dynamics Laboratory (GFDL), NASA's Goddard Institute of Space Studies (GISS), and the National Center of Atmospheric Research (NCAR), which all run state-of-the-art, sophisticated GCMs, whose results are the very heart and soul of the current climate debate, and which are similar to those arrived at by other modeling groups around the world.

At this point we will not go into any detail of the modeling and computational procedures applied in those GCMs, because they are very complex and are somewhat beside the point here for most purposes. There are a few items, however, which are of sufficient importance and to which we will return later on.



Courtesy Böttiger Verlags-GmbH

The cover of Gerd Weber's forthcoming English-language book.

We are now going to present the image of a future climate at twice today's atmospheric CO_2 level, and do this by giving a consensus view from the models, first on a global basis, and then in a little more regional detail as far as this is warranted by the horizontal resolution of the models.

In a 2-times-CO_2 climate, the best available model calculations expect:

1) Global temperatures will be 6-8°F higher than before we emitted trace-gases into the atmosphere.

2) At higher latitudes, this temperature increase would be 2-3 times as large as the global average, and in low latitudes, it would be less than the global average.

3) The temperature increase would be larger in winter than in summer.

4) Precipitation is expected to increase by about 10% on a global average, but is expected to increase more in mid- and high latitudes, remain the same in the subtropics and increase some in the tropics.

5) Furthermore, because of thermal expansion of the oceans, the sea level is expected to rise by 1-3 feet.

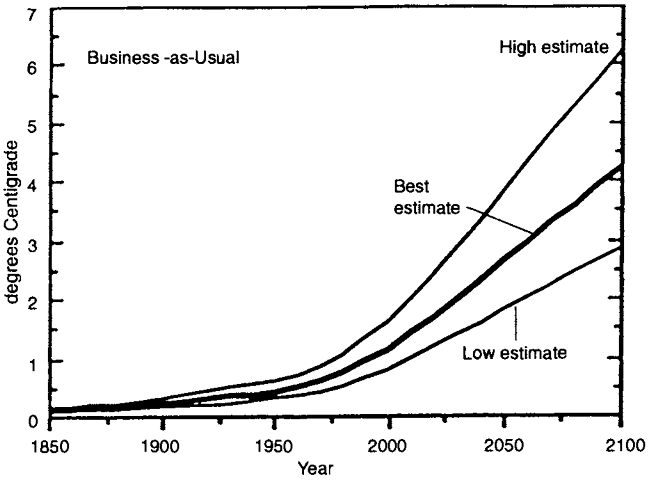
The Intergovernmental Panel on Climate Change (IPCC), the body instituted to probe into the greenhouse effect, arrived at conclusions which are broadly comparable. Some of their results and assumptions are shown in **Figure 4.** According to them, the equivalent CO_2 doubling may occur by the year 2030. Temperatures may have increased by 2°C by then. Additional warming is expected in the following decades until "equilibrium warming" is reached.

The "equilibrium warming" is the temperature increase calculated by climate models after all feedback mechanisms

FIGURE 4

Projected global warming from 1850-1990 into the year 2100

Realized temperature rise after 1765



Source: *Global Warming, the Rest of the Story*, Intergovernmental Panel on Climate Change, 1990.

This figure uses the IPCC "Business-As-Usual" trace-gas scenario to simulate global warming between between 1850 and 1990 thought to have resulted from the observed trace-gas increase and projects the effect of increased concentration of trace-gases into the year 2100.

have acted and after all delaying processes have ended.

One major example for such a feedback mechanism is the water-vapor feedback loop. It works like this: An initial increase of greenhouse forcing due to a trace-gas increase evaporates water wapor from the oceans. However, water vapor itself is also a greenhouse gas, and therefore the additional water vapor in the atmosphere causes more water vapor to evaporate (because if ocean temperatures rise, evaporation rises) and so on, until a new equilibrium of the energy fluxes is established. This feedback alone is important enough to account for roughly two-thirds of the additional greenhouse effect. In other words, without this feedback, temperatures, according to model predictions, would only increase by one-third of the value after feedbacks. This will be important to remember, because it means that the full effect will only become apparent after the oceans have warmed up and have provided the atmosphere with additional water vapor. Therefore, ocean temperatures and atmospheric water vapor content should provide valuable monitors of greenhouse-induced climate changes.

The envisioned temperature increases would indeed be very large, were they to occur, and put Earth into a climate it has not seen in over 100,000 years, eclipsing, by a large margin, temperature variations of the last few thousand years, which in all likelihood have only been between ±4°F.

Before we get into some of the possible drastic consequences this might have on nature and human activities in general, we will first consider the impact of such a climatic change on the U.S.

We do this by looking at the expected changes in temperature and precipitation at eight major U.S. cities, each representing a different climatological region. Those data are shown separately for summer and winter in **Table 1.**

The values given here have been interpolated from published results of the three major GCMs described above. To give you an idea of the degree of variation from model to model on a regional scale, both an average of all three models and the results from the individual model are given.

The variability among models is too large at present to put much confidence in any individual forecast for a given location. Therefore, we will consider the consensus or average forecast of the three main U.S. GCMs for the eight cities chosen.

Surprisingly, the average warming at all cities is nearly the same in winter as in summer, namely 6.8° and 7.0°F respectively. Even the geographical variations are comparatively small with a somewhat larger warming expected north within the continental interior, in Minneapolis and Chicago. It may be noted in passing that those temperature increases would be considered significant within the framework of the models, since the average error of the modeled and currently observed climate is in the neighborhood of 5°F. Therefore, the modeled temperature increases for a CO_2 doubling are much larger than the expected error margin. According to those model calculations, Chicago would enter into a climate—as far as temperature is concerned—which is presently observed in central Tennessee. This may be a welcome change for Chicagoans, who occasionally suffer from atrocious winter weather, but the summer swelter, now confined to the Deep South may extend all the way up to Chicago. New Orleans may then be in for even worse news as winters get milder, but the entire summer half-year would get incredibly hot and sultry, turning New Orleans' climate into today's Miami.

In those two examples, we only considered temperature changes and not precipitation changes. But, of course, it is of utmost importance in the climate change debate not only to consider one parameter such as temperature, but other important parameters as well, the main one being precipitation. No analysis of climate change can be complete without considering precipitation. For instance, it would be foolish to state outright, "The climate of Chicago will be that of Nashville, Tennessee" by only considering temperature. If precipitation decreased drastically under a warming scenario, Chicago's climate would not be like Nashville's but rather like the one of Dallas or Amarillo, Texas.

Let us therefore consider the modeled precipitation

TABLE 1

Climate model predictions for eight American cities in case of an atmospheric CO_2 doubling

Projected temperature changes in Centigrade

(1°C=1.8°F)

	Winter				Summer			
	GFDL*	GISS	NCAR	Mean	GFDL	GISS	NCAR	Mean
Minneapolis	7.0	5.0	2.0	4.7	8.0	3.0	2.5	4.5
Chicago	6.0	5.0	2.0	4.3	7.0	3.0	2.0	4.0
Denver	5.0	5.0	2.0	4.0	7.0	3.5	2.5	4.3
New York	6.0	4.0	3.0	4.3	6.0	3.0	2.0	3.7
Los Angeles	4.0	4.5	2.0	3.5	4.0	4.0	2.5	3.5
Phoenix	4.0	5.0	2.0	3.7	5.0	4.0	2.5	3.8
New Orleans	4.0	4.0	2.5	3.5	4.0	3.5	2.5	3.3
Miami	4.0	3.5	2.5	3.3	4.0	3.0	2.5	3.2

Projected precipitation changes in mm/day

(1 mm=0.04 in)

	Winter				Summer			
	GFDL*	GISS	NCAR	Mean	GFDL	GISS	NCAR	Mean
Minneapolis	0.5	0.4	0.7	0.5	−1.0	0.2	−0.1	−0.3
Chicago	0.4	0.3	1.0	0.6	−0.7	0.4	0.4	0.03
Denver	0.2	0.3	1.0	0.5	−1.0	−0.1	−0.1	−0.4
New York	0.4	0.3	1.1	0.6	−0.5	0.0	0.2	−0.1
Los Angeles	0.1	0.2	0.0	0.1	0.2	0.2	0.1	0.16
Phoenix	0.1	0.3	0.5	0.3	0.0	0.3	0.0	0.1
New Orleans	−0.1	−0.2	0.0	−0.1	−0.2	0.4	0.0	0.06
Miami	−0.2	−0.2	−1.0	−0.5	−0.4	0.3	0.0	−0.03

*GFDL=Geophysical Fluid Dynamics Laboratory
GISS=Goddard Institute of Space Studies
NCAR=National Center of Atmospheric Research
Source: *Global Warming, The Rest of the Story;* after data from U.S. Department of Energy, Report DOE/ER-0237.

changes. As we did before, we will look at an average of three GCM forecasts for the eight cities in Table 1, and we first do this for the summer months of June, July, and August. Those months are in the middle of the growing season, a time particularly susceptible to precipitation changes.

We notice at the very beginning that there is a remarkable scatter from model to model in the predicted precipitation changes. In Chicago, for instance, one model predicts a decrease of almost 8/10th of an inch per month, while the remaining two forecast an increase of 4/10th of an inch per month.

The consensus forecast for all stations calls for a decrease of monthly precipitation by less than 1/10th of an inch. The average monthly precipitation of the stations used here is approximately 3-4 inches. Therefore, the forecast precipitation change is only a very small fraction of today's observed precipitation.

If we furthermore consider the margins of error of the modeled present-day precipitation, we realize that they are many times higher than the modeled precipitation changes resulting from a doubling of CO_2.

From this we can only conclude that, on the basis of current model forecasts for the locations considered here, there will be no significant precipitation changes during the summer months. Looking at winter precipitation, the situation is somewhat different, insofar as there is a slight to moderate increase in modeled precipitation, particularly at those locations were there was a decrease in summer. In general, precipitation seems to increase over the northern half of the country. The increase in winter precipitation appears to be larger than the occasional decrease in summer. Since winter precipitation is decisive for water management (most aquifers get recharged in winter), it is hard to construe a worsening water supply situation on the basis of current model forecasts; the available evidence rather points to an improvement in most areas. This appears to be the case even in those areas which already are under water stress today, namely the desert Southwest.