Washington Roundtable on Science and Public Policy

Climate Forecasts, Global Warming and the National Assessment

by
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January 23, 2001

The latest report of the Intergovernmental Panel on Climate Change (IPCC) projects a temperature rise over the next hundred years on the order of 1.5° to 6° Celsius. Today, we are going to talk about the models on which such predictions are based, how well the models simulate the real world, and whether or not it makes sense to derive policy issues on the basis of what they say. One question is whether these numbers are reasonable. As originally written, the IPCC document indicated a global air temperature rise of 2.5° to 4° Celsius with a doubling of greenhouse gases; very lately, the upper end of the spectrum has been increased to 6° Celsius for reasons that may or may not be obvious.

Let me begin by saying that I am not opposed to models. Models can be very useful in their place. But one concern I have is whether our present state-of-the-art climate models really can be used to evaluate climate change.

Climate change research generally focuses on three main areas. The first is *long-term* climate change, using proxy records that extend back tens of thousands of years. The second is *near-term* climate change, looking at the last 100 to 150 years – a period of time when we have had more detailed observations of climate variables, through station observations and satellites. Both of these research areas look backward: they put climate change in the context of what has happened in the past and therefore what may be expected in the future. The third area of climate change research is forward-looking, into the so-called "crystal ball" of computer models.

Models attempt to reflect the real climate by creating a representation that possesses the relative characteristics of what we want to convey. To answer the question, "Is a model any good?", you really need to ask, "What do you want the model to do?" For instance, a miniature, scale-size train locomotive might not be a bad model to use in a scale-size railroad diorama. But that same model would not be a very good one to simulate what would happen in a 60-mile-per-hour head-on collision with another locomotive. In other words, a model is really only as good as the way in which it represents reality *relative to what we want the model to represent*.

The two climate models that form the crux of the National Assessment of Climate Change are the Hadley Centre Climate Model, from the Hadley Centre for Climate Prediction and Research in the United Kingdom Meteorological Office; and the Canadian Global Coupled Model, from the Canadian Climate Center. These climate models are not physical representations, like scale-model locomotives, but mathematical representations in computer space. Specifically, both the Hadley Centre and Canadian models are "coupled General Circulation Models" (GCMs). Researchers "couple" models of atmospheric, ocean and land-surface interactions to describe the interrelationships of the components of the climate system: a circulation model describing atmospheric dynamics and flows is coupled to an ocean model describing ocean dynamics, which is coupled to a cryospheric model of ice flows, and so forth.

The question, of course, is "How well do climate models actually simulate all of the features that affect the earth's climate?"

About 13 years ago, Cort Willmott and I put together a global precipitation and air temperature climatology that many others and we have used to evaluate climate models. My research emphasis is largely in precipitation, and so when I look at a climate model, that's usually what I look at first. Climate modelers say you should look at air temperature first, because that's where the emphasis of global warming lies and where they have tuned their models to look good. But I think precipitation is a much better indicator of a climate model's efficacy, because it is more fully integrated into the climate system. Furthermore, precipitation is not simply an ancillary variable. I would argue that, in some cases, humans and plants will respond faster to changes in precipitation than they might to small changes in air temperature.

In the precipitation field, the two important components are what I call the M&Ms: moisture and mechanism. For a model to simulate precipitation correctly, it must have the correct moisture content of the atmosphere, and there must be an appropriate mechanism to trigger the moisture to precipitate out. For several reasons, however, precipitation is one of the most difficult things to simulate in a General Circulation Model. First, most GCMs have a spatial resolution of about 2.5° of latitude by 2.5° of longitude. This is a huge system, some 400 miles on a side. Convective systems occur far below that resolution. A hurricane cannot be simulated by a GCM because the resolution simply is not there.

There are other difficulties in simulating precipitation, including a numerical problem with instabilities that arise when small moisture amounts change on several orders of magnitude. But perhaps the most important reason GCMs have trouble simulating precipitation is that anything you do wrong in a climate model is going to show up in precipitation. If you get the topography wrong – if you put mountains in the wrong place, which some models have done – then the orographic uplift will be incorrect, and thus precipitation driven by mountain airflow is going to be incorrect. If you get atmospheric circulation wrong – if you bring moisture in from the wrong area and move it in the wrong direction – the supply of moisture will be incorrect and thus the moisture available for precipitation will be incorrect. Get anything wrong about the boundary layer interaction, or clouds, or surface evapotranspiration (evaporation from lakes, streams and the ocean, or transpiration through the leaves of plants), and this will adversely affect precipitation.

But this is also a two-edged sword: Anything a model gets wrong in its simulation of precipitation will effectively feed back into each of these other processes (with the exception, obviously, of topography). Wrong estimates of precipitation rates affect cloudiness, which in turn affects the energy balance by changing the distribution of reflected solar energy versus trapped long-wave energy. Wrong estimates of precipitation rates also affects the amount of moisture available for plants at the land surface.

And getting precipitation rates wrong can change air temperature to a considerable amount. I won't go through the mathematics involved on this slide, but if you do the equations, you find that about 0.1 inch of rainfall (not a very large value: we see some rainfall rates on the order of one to two inches an hour) can affect the energy budget enough to change the atmosphere's temperature by almost 0.3°C. Yet air temperature is what the reports use as the key indicator of climate change, as we saw in the IPCC report.

Well, using the climatology we put together thirteen years ago, Cort Willmott and I compared global precipitation numbers in four climate models. Although this comparison is somewhat out of date, I will discuss it because with respect to their simulation of precipitation, the models have not become any better.

We looked at three models from the United States: from NOAA's Geophysical Fluid Dynamics Laboratory (GFDL); from NASA's Goddard Institute for Space Studies (GISS); and from the National Center for Atmospheric Research (NCAR) in Boulder. We also looked at the model from the United Kingdom Meteorological Office (UKMO). Averaging spatially and temporally, we created one number for monthly precipitation averaged over the globe. And we found first, quite a bit of variability among the models, and second, quite a bit of difference from observed values.

Notice, below, that every model is in agreement that in our hemisphere, January is drier than July. You would expect the opposite: our ocean hemisphere produces lots of evaporation in the summer. And in reality, observed temperatures do show July is drier than January. But every model gets it wrong:

Global Precipitation Estimates

Model	January	July
GFDL	3.13 in.	3.35 in.
GISS	3.89 in.	4.06 in.
NCAR	3.76 in.	4.24 in.
UKMO	3.54 in.	3.93 in.
Observed	4.37 in.	3.44 in.

Other scholars also have done model intercomparisons, some for the IPCC itself. In 1999, Larry Gates of Lawrence Livermore National Laboratory presented zonally averaged global precipitation by 31 general circulation models. Most modelers I talk to about this say it appears that the models look pretty good; we know that mid-latitudes should have increased precipitation and we should have a wet tropics and that is exactly what you have. But anyone in Introductory Climatology 101 knows that; we shouldn't assume that a model is a good one because it pulls out the obvious.

More important, there is huge variability among the underlying models. But because Gates' model intercomparison is based on what are called "merged ensembles" (averaging the 31 models and then comparing that to reality), when one of the model does poorly in one area and another model does poorly in another area, and so forth, the differences get averaged out. It's a lot like a professor who gives the class a test, selects the average grade for each question, and then evaluates how students are doing on the basis of those average grades. A majority of the students may be getting each question right, but overall, most of the students may be failing. The problem is, we do not evaluate climate change from model ensembles, but rather, we look at climate change from the individual models, and that is how the models should be evaluated.

In an evaluation of the Hadley Centre and the Canadian Climate Center models, Dougherty and Mearns used our global air temperature and precipitation climatology dataset, subsetted for North America. Comparing what the models see as present-day conditions to actual present-day conditions, the resulting climate maps show that the models differ considerably from the observations both in amount and in pattern.

In the winter months, for instance, the Hadley Centre model has considerably cooler temperatures than actually observed (a difference of -3° to -6°C) over much of the southwestern third of North America. In the Canadian Climate Center model, a substantial area – all the southern half of the United States – is more than 9°C colder than actual observations. In other areas, the models show warmer average conditions than observed. And much the same difference between modeled and observed temperatures appears in the models' treatment of the other seasons.

Remember, 2.5°C to 4°C is the *range of predicted global change* over the next century. In other words, the uncertainty in the models relative to the observations is as great or greater than the models say the change is going to be. This is important to note because the uncertainty is larger than the signal!

So what we have is a signal-to-noise problem. It is like trying to hear a distant AM radio station when there is considerable static. A sea of noise swamps the climate change signal we are trying to see. That noise is a function of several things, such as natural variability in the climate system and year-to-year variation, but it is also a function of how much uncertainty there is in the model generating the scenarios. In a sense, we are simulating a very small signal that can't necessarily be resolved within the sea of uncertainty that presently exists between the model and the observations.

We only have one *known* scenario, and that is the present day-conditions. From that scenario, we see that both the Hadley Centre and the Canadian Climate Center models generally exhibit significant differences from the observations. In our discussion here, I am not going to quibble over a degree or two, but when the differences get to be on the order of six, nine, twelve degrees, a serious signal-to-noise problem exists.

For example, take the question of what's going to happen in the central region of the United States. In 1988, there was a major Midwest drought, and people were concerned that global warming would lead to more. Five years later, the floods of 1993 led to major Midwest flooding, and that was also considered a signal of potential global warming. So, will the Midwest suffer extreme droughts, extreme floods or more of both?

Well, if we cannot reasonably simulate the present climate, how much faith can you put in what the crystal ball of the models projects out a hundred years? And the United States, I should point out, is an area where we have considerable observational data. Thus, when the model differs considerably with our observations, the error probably lies with the model and not with the observations – and certainly not to the extent to which we are talking about, 4°, 5°, or 6°C.

Moreover, if global change prognostications are really to be believed, the two models should look similar. When one projects an increase in temperature and the other sees a decrease, which are you going to believe?

Take this figure from the National Assessment of the annual surface air temperature. In the Hadley Centre Model, by 2030 the changes are generally less than 2°C everywhere except in the central Rocky Mountain regions, where they are a little bit higher, up to about 2°C. Alternatively, in the Canadian model, we see a very low warming along the coastal fringe, but significant warming (on the order of 2°C to 3°C) in the middle of the United States.

So if you are going to make a forecast for, say, the Ohio River valley, is the increase 1°C or 3°C? The two models have different answers. And we know they are not starting from the same place – they differ substantially from what reality looks like – so are either correct?

It gets worse when you push this forward in time over the next hundred years. The Canadian Climate Center model, which seems to indicate more climate change than any of the other models, shows increases on the order of 5°C and higher over virtually all of the United States with the exception of the Pacific Coast and southern Florida. If you compare that with the Hadley Centre model, that only happens in the mountainous regions of the west. In the eastern two-thirds of the United States, the temperature change is much lower, and the pattern is completely different. So if you ask what will happen in the U.S. Southeast, the correct answer is that we don't know. The two models, even if their prognostications are to be believed, give completely different answers.

Now to some extent, of course, the model simulations of air temperature are contrived. They tend to tune air temperature so that the model at least looks comparable to the observations. But precipitation is a much harder field to tune. Moreover, as we saw, a slight change in the precipitation can give you a considerable difference in air temperature. So if you tweak air temperature to look acceptable, you might really goof up the precipitation.

Well, that is in fact what happens. In one model comparison that Tracy DeLiberty and I did for a Department of Interior project, we examined the southern Great Plains region. The two models we considered (one of which was the Canadian Climate Center model) both agreed that the precipitation was lower in northwestern Louisiana, than it was in northeastern Colorado. Now, you don't have to be a geographer to know that rainfall is higher the closer you are to the source of moisture, which in this case is the Gulf Coast. And the observations clearly bear that out. But in the models, because of orographic uplift, there is far more rain in northeastern Colorado than observed, and much less rain than observed in northwestern Louisiana.

So, particularly in the middle of the United States, the models are getting the precipitation patterns completely backward. Based on this, the question then is, "How can we ever hope to use a climate model to answer questions about what will happen in specific regions: will we get more floods, will we get more droughts, or what?"

Thus, the models simply don't look like reality in terms of air temperature or precipitation. Going back to our model train analogy, what we see here is something that doesn't behave like a real railroad locomotive for our application. So is what happens to the model train extendable to what would happen in real life? I would argue, no; and in the case of climate models, I would argue exactly the same.

Coming back to climate model prognostication, what will happen in the next twenty-five years or so? We have huge uncertainties, huge noise, and an awfully small signal. The signal-to-noise ratio is extreme. You would never be able to hear that distant station on the AM radio with considerable static. In other words, the model uncertainties are so large relative to what the model says is going to happen, that you cannot really trust the model to tell you what will happen.

Consider now the climate variability. If you wish to describe the earth's climate, you would hope that the model would be able to replicate its interannual variability. We do not expect a model to predict a flooding outbreak or drought in a specific year in the far future, but we do expect that the variability of climate from year to year would resemble the variability that we observe. Yet a recent comparison of four or five models finds that the variability of the models is exceedingly low compared to the natural variability. In these models, every year resembles almost every other year: the interannual variability simply is not reproduced.

In summary, climate models provide estimates of globally averaged precipitation to within only about 20% of the observations. They simulate the general pattern of zonally averaged precipitation, although uncertainties can become far greater when specific areas of the globe are examined. For regional scale assessments, particularly over the United States, climate model simulations are extremely poor. The difference between the model simulation and the observations are frequently off by as much as an order of magnitude. Thus, the global or zonal average of precipitation may be reasonably simulated for the wrong reasons. In other words, although these values may look reasonable, it is probably not because the model is able to simulate what is actually happening.

The last issue I want to mention is that with global warming, it has often been said that we will see an enhanced hydrologic cycle. For instance, the IPCC Summary for Policymakers states, "warmer temperatures will lead to more vigorous hydrologic cycle." (*i.e.*, under global warming, we should have more floods and droughts in some places and fewer floods and droughts in others – that is like saying that some people will do better on an exam and some will do worse; or in other words, really saying nothing at all.) The

IPCC also notes "several models indicate an increase in precipitation intensity, suggesting a possibility for more extreme rainfall events." So, of course, any time there is a flood or drought, we can expect to hear, "see – that is proof of global warming."

But if you read deeper into the IPCC Assessment, you find that there is nothing behind these statements. The actual document says: "In the first few analyses available, there was little agreement between models and the changes in storminess that might occur in a warmed world. The conclusions regarding extreme storm events were obviously more uncertain." Does the Summary represent the document? Well, this is one case where it clearly does not and I can tell you, there are fistfuls of similar cases.

In fact, elsewhere the IPCC Policy Statement itself states, "there is no evidence for extreme weather events or climate variables increasing in the global sense." The IPCC report actually found that variability in much of the northern hemisphere's mid-latitudes has decreased as the climate has become warmer. Variability has *decreased*. That is not an enhanced hydrologic cycle. Or, take the report of the water sector of the National Assessment: "There has been no trend in North America-wide storminess or storm-frequency variability found in the record of storm tracks. The model projections show no sensitivity to elevated carbon dioxide. It should also be clear that little can or should be said about variability of storminess in future, carbon-dioxide-enriched years."

In other words, we can't say there will be an enhanced hydrologic cycle. And this is what scientists are actually saying in climate-change documents, despite what you will continue to hear in the media about more floods and more droughts.

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<u>Question and Answer Period</u>

Question: What do models do about cloud condensation nuclei?

Legates: In some models, ironically, clouds and precipitation are two separate processes. The clouds are there as far as the radiation balance is concerned – to reflect off sunlight or to trap long-wave radiation. For precipitation, the model simply looks at humidity characteristics. If humidity characteristics were to go above a certain predefined level (usually 80%) over that large region, then you will start to condense moisture and get precipitation. I don't think cloud condensation nuclei play a key role at the scale of climate models, because the condensation nuclei are going to be at an almost molecular scale level.

Most people agree that there is enough cloud condensation nuclei in the atmosphere. So if there is a process present to induce precipitation, then the presence or absence of cloud condensation nuclei is not a limiting factor. Now with cloud seeding, using silver iodide, you might actually get enhanced precipitation – you fool the cloud into thinking that there are more ice crystals present when they are not, and that is why some people think you should cloud-seed and others don't. The models don't get that detailed and specific. Essentially the only particulates in the atmosphere as far as the models are concerned are sulfates and they do not enter into this calculation at all, in terms of precipitation. In most cases, a simple change in the surface albedo simulates the effect of sulfates. Thus, they are not really modeled at all, you just tweak the surface albedo and say particulates in the atmosphere would have essentially the same effect.

Question: Could you talk about how the models attempt to come to grips with non-linearity problems?

Legates: Part of the problem with models is that the atmosphere works on a different spatial scale than the oceans. In the atmosphere, you can model on the large-scale and still get a good simulation, because most of the energy in the atmosphere is contained in larger-scale phenomena. However in the oceans, most of the energy is transmitted on a very small scale, and you need a very fine resolution to be able to resolve, for example, the eddies that spin off of the Gulf Stream and other warm-water currents. But you can never run the atmosphere at the fine same resolution.

So "coupled" models are actually "de-coupled" models. That is, you run the atmosphere for a while, and hold the oceans constant; then you hold the atmosphere constant, and run the ocean model. And you run each one off-line by changing the input and attempt to get some sort of steady-state or change as you oscillate back and forth. So coupling these systems is problematic from a computational standpoint. But if a model is going to be useful for determining the future, it had better represent the way the present conditions are. So if they are not connected together, that should indicate a limitation in the model.

That is not to say that we recognize this is a problem and simply proceed. We should recognize that this is a limitation of the model that precludes its use at this time; we should not be using the models to drive inferences. We need more understanding and more refinement.

Question: What would be the likely rebuttal from the authors of the *Summary for Policymakers,* whoever they may be?

Legates: One is: "Yeah, we realize that there are limitations to climate models, but it is the best we've got. And we've been refining the models over the years." I will not deny that. Models have gotten substantially better than they were in the early 1980s, when we were starting to investigate this question. (At that time, they did the radiation well, but clouds were held constant, ice was held was constant, the land surface was held constant, oceans were held constant. Over time we started to incorporate more feedback. The more feedbacks we incorporate, the more we find most feedbacks are negative. That is, they inhibit change. For example, when you increase cloudiness, you may increase nighttime temperatures but decrease daytime temperatures, whereas when you held clouds constant, the daytime temperatures would generally dominate and you would get a larger temperature change.)

But the concern I have is that the models haven't gotten to the point at which they are really able to examine the fidelity of changes in the climate system, either spatially or temporally, in order really to represent the climate system, so that a change can be linked to changes in the future. They say the models have progressed quite a bit. I say that they have not progressed enough.

Other defenders of models say, "All these nay-sayers are funded by coal and gas." Well, my research dollars have been exclusively from the federal government, so as far as I am concerned, that is not true. But for people who seem to think that federal dollars are somehow "clean money," I can tell you, that isn't the case. The government has become the goose that lays the golden egg. The last thing many scientists want you to do is stand up and say: "We don't know what's going to happen. Anything could. Our science hasn't come to that point yet." In which case, people eventually conclude: "Fine, maybe we should move money away from that and spend money somewhere else." And all the sudden, you have killed off your golden goose.

Question: Do the National Assessment and the IPCC listen to critics of the models?

Legates: I attended the meeting in Atlanta on the National Assessment, and I can tell you that many of our concerns actually did make it into the document. But you have to read the *document*. The Summary is not a summary of the document. But 99% of the people never get past the Summary.

Regarding the IPCC: I am not a reviewer, because reviewing the IPCC allows them to put your name on the list, and then you become one of the "major scientists," twenty-five hundred or so, that are supposedly "all in agreement." I do know that there was a lot of concern, but not much of that made it into the final document.

Question: Please explain this business about "tuning" models to ensure they agree with the current climate. Is that just done for the temperature field?

Legates: Usually, because that is the field most everyone looks at. There is something called a "flux-adjustment." The idea is that in some cases, the energy balance between the earth's atmosphere and the surface isn't the way it's supposed to be, and so a flux-adjustment is applied in order to make it work. The tuning parameters are what other people would call "fudge-factors." It's what you have to put in the model to make it look reasonable. Some models require a lot of tuning and some require even more.

Question: Reading the popular press, I get the impression that the range of temperature forecasts is narrowing over time, and that the average is declining over time, but in the recent press, I've seen a figure of 11°F.

Legates: The high end of the IPCC forecast was 6°C, which is 10.8 Fahrenheit; that's where your 11°F comes from. The idea is people are only going to get motivated if we have a high-end scenario. If they see the high-end ratcheting downwards, they say: "Well, this may indicate uncertainty and not as big a change." A famous scientist, Steven Schneider, said at one point: "We may have overstated the climate case. But we had to in order to get people to react." As a scientist, I find that completely appalling. A scientist is supposed to present the facts. Saying, "I have inflated something but I had to, in order to get you to respond" is saying that I lied to you. I don't think the end ever justifies the means, and particularly in this case.

Question: I'd like to ask about IPCC's use of forty possible scenarios, instead of several model predictions. Are they giving up on the idea that they can predict anything?

Legates: They aren't referring to forty different models; there are forty different scenarios of how we may cause climate change through varying carbon production. One scenario is a business-as-usual scenario; one is in which carbon production increases say 10% per year; another say 20% per year, and so forth. And because the models are very sensitive to carbon dioxide in the atmosphere, if you increase the rate of carbon production, the models give you larger changes in air temperature. The faster the rate of increase, the faster the air temperature increases. The idea of multiple scenarios, I feel, is to be repetitive. It is a way of saying that every increase in greenhouse gases will be bad and multiple scenarios just overwhelm you.

Question: The difference between the scientific document and the policy summaries suggests that scientists don't control the policy summaries and recommendations, and some other people do. What is the responsibility of the scientific community, meaning university professors, the professional associations, the journals, the editors, as well as government scientists, to oversee that process?

Legates: Well, the apparent difference between the scientific document and policy summaries is because the IPCC is not a scientific document, but a political one. Politicians and some scientists alike have axes to grind and when the document was written, it clearly was slanted toward global warming gloom-and-doom scenarios.

I think that as a scientist, you are required to report on what you have found – just the facts. That is because science is supposed to be verifiable and reproducible. As a scientist, if one makes errors or is fraudulent, the scientific community will dismiss that work because what has been done is not reproducible. But some scientists cannot distinguish between advocacy and science. The end justifies the means so that if they overstate ideas by ignoring key facts, that is acceptable since their misuse of science is validated by their advocacy goals.

I wish that the scientific community as a whole would come together and indicate exactly what most scientists really believe. Many scientists have indicated to me that they are concerned about the overstatement of the global warming issue by a handful of high-profile scientists whose careers have been based on making global warming an international issue. Most scientists, I feel, fall into the category of "the future is still uncertain" and not "the proof is all around us". This is quite contrary to the line that the media usually portrays. The IPCC really is a sham because while it gives the impression of being a consensus of scientists, it is simply a political document prepared by advocacy scientists with a large ax to grind.

For example, in 1997, American Viewpoint surveyed thirty-six state and regional climatologists and asked them: "Have the weather events in the last forty-five years been more severe or frequent?" Only three said "In our state, yes, and it's caused by global warming." Seven said "yes, but it's not due to global warming." Twenty-six said "no, not at all." Asked their views on the statement, "The overwhelming balance of evidence and scientific opinion is that global warming is now a fact," one "strongly agreed," twelve "somewhat agreed," but twenty-one were in disagreement. This mimics what I hear among the rank and file of climatologists; most aren't what I would call "skeptics" but neither are they ready to agree that anthropogenic global warming is the end of civilization or a foregone conclusion.

I would like to see someone fund a comprehensive survey of atmospheric scientists. I think that you would find the results to be similar to those obtained by American Viewpoint – and I think that you also would find that most of the global warming proponents work at government labs where continuing the stream of federal funds is of paramount importance. Although I cannot address their real motives, I think it appears obvious why it is in their best interest to be global warming advocates.

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