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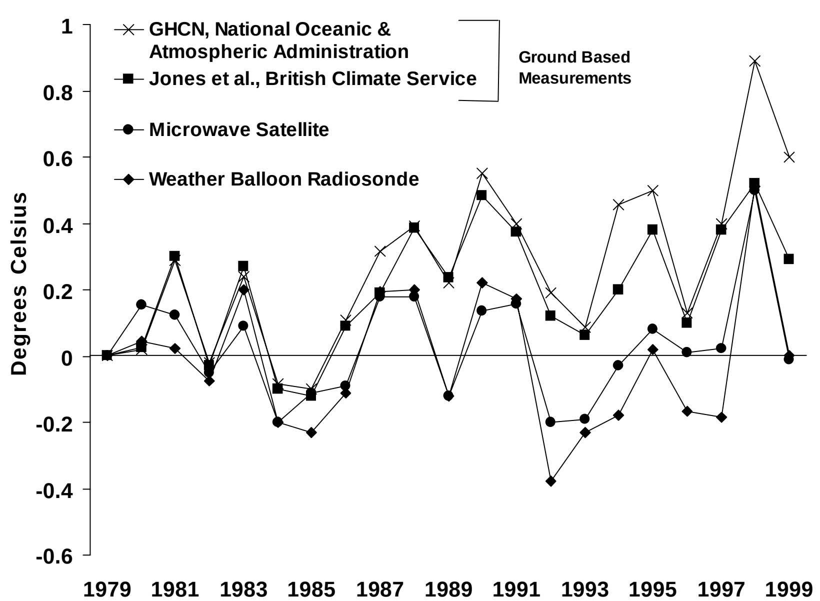
Limitations of Climate Models as Predictors of Climate Change

by David R. Legates

World leaders are making critical decisions based upon predictions of General Circulation Models or Global Climate Models (GCMs) that humans are causing global climate change or global warming. Global climate models attempt to describe the earth's climate and are used in a variety of applications. These include the investigation of the possible causes of climate change and the simulation of past and future climates. But these models are limited in important ways, including:

- an incomplete understanding of the climate system,
- an imperfect ability to transform our knowledge into accurate mathematical equations,
- the limited power of computers,
- the models' inability to reproduce important atmospheric phenomena, and
- inaccurate representations of the complex natural interconnections.

Temperature Departures from Average Since 1979



Source: Dr. S. Fred Singer, Science and Environmental Policy Project.

These weaknesses combine to make GCM-based predictions too uncertain to be used as the bases for public policy responses related to future climate changes.

The Limits of Human Knowledge. The world's best scientists have only an incomplete understanding of how the various atmospheric, land surface, oceanic and ice components interact. Even if their understanding of the climate system were perfect, scientists would still face challenges. Consider that while scientists do have a general idea of the complex interrelationships of the atmosphere and the oceans, expressing this knowledge mathematically is very difficult.

The Limits of Computing Power. GCMs are limited in important ways. Global climate is produced through a variety of processes and interactions that operate on a wide range of scales, including molecular, regional, continental and global. Changes in climate occur from physical interactions that take place on any or all of these scales. The changes, and the resulting weather patterns, can occur nearly instantaneously or they can take decades or millenia to develop. Unfortunately, the computers and programs that run the GCMs are limited to gross representations of the geographic, geologic and atmospheric details that they use to run climate simulations. Thus, many small-scale features, such as a temporary but significant shift in the prevailing winds or unusually dry surface conditions due to increased evaporation from forest fires and high winds cannot be represented, even though they may significantly impact the local, regional, or even global climate.

Indeed, GCMs can *at best* represent only a thumbnail sketch of the real world, with spatial resolutions no finer than regional areas a thousand miles square. Many topographical, geological, atmospheric and biological variations can occur within any contiguous thousand square miles. For instance, GCMs might average rainfall amounts and wind velocity over large diverse land surfaces which could include arid mountain plateaus, low-land deserts and temperate coastal rainforests. But, even modest topographic changes – for instance, a new housing development that paves over farmland and drains a wetland area — could render a model of land-surface interactions inaccurate.

Resulting Model Breakdowns. Given the limitations noted, GCMs simply cannot reliably reproduce

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climate systems. Commonplace events like precipitation and the passage of typical weather fronts are difficult enough to depict; truly complex phenomena, such as hurricanes, thunderstorms and tornadoes, may be represented so poorly that they simply cannot be relied upon. El Niño, La Niña and the Pacific Decadal Oscillation are examples of complex climate patterns that are inadequately reproduced or completely absent in GCMs.

In addition, global average temperature is measured by three different instruments — ground-based thermometers, weather balloons and global satellite observations — with each system covering a slightly different range of the earth's atmosphere. The data they provide is conflicting. Whereas both the global satellite network and weather balloon observations show a modest cooling trend during the past 25 years, the ground-based thermometers show a modest warming of approximately 0.13 degrees Celsius per decade.

The GCMs display two flaws related to measured global temperatures. First, they show global temperatures rising across all levels of the atmosphere, a finding not reflected in reality. [See the figure.] Second, the lowest predicted global temperature measurement of the GCMs is nearly three times more than the temperature rise measured by ground-based thermometers. Thus, the GCMs do not reflect the temperature differences or the direction of temperature change within various levels of the atmosphere, nor do they show the actual amount of temperature change.

Finally, GCMs ignore the interconnected nature of climate processes and how an inaccurate simulation of one introduces errors into every other related process. A simple model for precipitation involves scores of variables. But a single error, say in representing atmospheric moisture or deciding what mechanism is causing precipitation, will make the simulation "wrong." For example, precipitation requires moisture in the atmosphere and a mechanism to force it to condense (i.e., by forcing the air to rise over mountains, by surface heating, as a result of weather fronts or by cyclonic rotation). Any errors in representing either the atmospheric moisture content or the precipitation-causing mechanisms will produce an erroneous simulation. Thus, GCM simulations of precipitation will be affected by limitations in the representation and simulation of topography.

Inaccuracies in simulating precipitation will, in turn, adversely affect the simulation of virtually every other climate variable. Condensation releases heat to the atmosphere and forms clouds, which reflect energy from the sun and trap heat from the earth's surface — and both sources of heat affect air temperature. This in turn affects winds, atmospheric pressure and atmospheric circulation. Since winds drive the upper currents of the ocean, the simulation of ocean circulation also is adversely affected. Additionally, inadequate simulations of precipitation lead to inaccurate assessments of soil moisture. Since vegetation also responds to precipitation, the entire representation of the biosphere becomes open to question. This is not to say that climate scientists lack skill or dedication; it is to reiterate the extraordinary difficulty of producing accurate climate models.

More than just long-term average and seasonal variations go into estimating the extent of climate change. Climate change is likely to manifest itself in small regional fluctuations. Moreover, year-to-year variability is important. Much of the character of the earth's climate is in how it varies over time. GCMs that simulate essentially the same conditions year after year, as virtually all climate models do, miss an important aspect of the earth's climate. Thus GCMs' predictive powers must be evaluated in light of each model's ability to represent the global climate's holistic and variable nature.

Although GCMs are not weather prediction models, climate is nevertheless an ensemble of weather events. The utility of a climate model is not in predicting whether it will rain in northern Florida on a certain afternoon. What is of interest is to determine the long-term probability that future precipitation will be significantly different — in frequency and/or intensity — from what it is today. Will the winter of 2048 be warmer or colder, wetter or drier than present conditions, and if so, by how much? If climate models cannot simulate processes known to drive daily weather patterns, to what degree can their climate predictions be believed?

Conclusion. Climate is to some degree a representation of the average of weather events that occur. If the frequency and locations of weather events are simulated inaccurately or not at all, the reliability of climate change prognostications is undermined. While GCMs cannot be expected to simulate future weather, they should be able to accurately depict the earth's present climate and vitality. Since they cannot, GCM predictions of climate change are statistical exercises with little bearing on reality.

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