Lessons from Climate Change Modeling

For SEs and Climate Change Scientists, Predictive Ability Rests in Finite Element Model Quality

By David Pierson, S.E.

For any who have read my previous articles, it will be no surprise that the views I present herein might be considered heretical. But, after much thoughtful consideration of what appears to be a prevailing attitude among many of the structural engineering community regarding the global climate crisis, I feel a responsibility to present what I believe is a fair critique of what is often (in my view, incorrectly) called *Settled Science*. I do this because I feel it is not in the best interest of our profession to blindly accept as settled something that is not actually settled. Our reputations will suffer if we accept, without debate, hypotheses that are not proven and may be shown in the future to be wrong (particularly if we "go along" to look fashionably hip to the public or our clients).

For some context, consider the experience of Dr. Dan Shechtman. In 1982 he claimed to have discovered a new crystal with an aperiodic structure (five-fold symmetry). The discovered structure was called a *quasicrystal*. Since the types of possible structures in crystals had been considered a closed subject by almost all scientists since the late 1800s, and this did not agree with what was "known," Shechtman was vilified for his claims. A Nobel Laureate publicly shamed him, saying, "There are no quasicrystals, only quasi-scientists." However, some 25 years later (after complete vindication), when Dr. Shechtman was awarded the Nobel Prize, he said that this experience "has given us a reminder of how little we really know and perhaps even taught us some humility." Words of Wisdom, indeed.

To begin, a few key points:

1) The climate is changing. On this, there is 100% consensus. It has been for millennia and will continue to change for millennia into the future.
2) Carbon dioxide is a greenhouse gas. On this, there is 100% consensus.
3) Emitting carbon dioxide (and methane) increases the amount of greenhouse gas in the atmosphere. On this, there is nearly 100% consensus.
4) Increasing greenhouse gas concentration in the atmosphere tends to warm the planet. On this, again, there is relatively significant agreement.
5) However, the unknown effects of feedback, which must be assumed, along with many other assumptions inherent in climate modeling, means that there is NOT consensus on the relative impact of greenhouse gas emissions on overall warming.

The first four points outlined above have led many to believe that *Settled Science* proves humans have been the major cause of Climate Change over the past 50 years. Unfortunately, in our society today, if you do not publicly accept the dogma of the *Settled Science* – i.e., that we "caused" climate change and can, therefore, "un-cause" it – you and your theories are dismissed as heretical.

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I recently had the chance to read a very well-written book explaining climate science and climate modeling. Steven E. Koonin, a former Obama Administration Undersecretary for Science in the Department of Energy, wrote the book *Unsettled*. I highly recommend it. Dr. Koonin is a highly respected physicist who has spent much of the past two decades studying climate science and the UN Assessment Reports. On page 192 of the book, when discussing "*Who Broke the Science, and Why?*" the author states:

> "Scientists not involved with climate research are also to be faulted. While they're in a unique position to evaluate climate science's claims, they're prone to a phenomenon I call 'climate simple.'"

He then defined *climate simple* as an "ailment, in which otherwise rigorous and analytical scientists abandon their critical faculties when discussing climate and energy issues."

I took this personally as a challenge to dig deeper into the matter and to speak up, hence this article. I am not a climate scientist but I can reason and think critically. Among structural engineers, this does not make me unique.

Perhaps the most interesting thing I learned was how climate models are created. It is just finite element analysis. Structural Engineers understand this; finite element models are fundamental to our daily activities.

So, first off, here is an illustrative hypothetical. Imagine that you were tasked to analyze a building in a high seismic region. You were to perform a non-linear dynamic analysis. You utilized a large suite of ground motion time histories from past major earthquakes in the analysis. After carefully modeling all elements and inputting all the relevant structural and soil properties and characteristics, you ran the analysis. Success! You found that the building performs extremely well, with the residual inelastic deformation limited to easily reparable links, even after the worst earthquakes. Imagine that you were then told that the building you modeled actually was built in 1991 in California, and collapsed in the Northridge Earthquake. Obviously, the predictive results of your model did not match reality.

After this experience, would you expect anyone to trust you to model and design their building to survive a future earthquake? Reason says no. Your modeling prowess would be critically questioned.

Here is a short summary of what I learned about climate models. First, climate models are just complex finite element models. The elements are 1 km thick shells with 10 or more layers surrounding the globe. The mesh is what we engineers consider coarse – 100 km square at the atmosphere and 10 km square at the oceans. The models have many variables in the differential equations that must be solved with time steps as the elements change over time. For model initialization and tuning, many assumptions must be made. One example is that each element must be assigned a single value for each variable – even though cloud cover, temperature, precipitation, wind, convection, etc., all vary significantly over a 60-mile-square area of the earth.

We understand in our structural models that a very coarse mesh is not as accurate as a finer mesh – so why such a coarse mesh? It comes down to computing power (the same problem we have with our models, right?). With the millions of elements in the coarse mesh and using a 10-minute time step, the most powerful computers we have today can take about one to two months to run a 100-year climate simulation (depending on how sophisticated the equations are). If the mesh is finer, the time step must also decrease to "keep up," so the required computing time increases exponentially. If the grid at the atmosphere was reduced to 10 km square shells, the resulting 100-year simulation could take decades to run with today's computers. In other words, it is not currently feasible. This will, fortunately, improve over the next few decades, and eventually, our computing power (i.e., quantum computing) will allow much more sophisticated models.

The critical takeaway is this. Thus far, climate models have been unable to correctly produce results that match what actually happened in the past century, particularly concerning the warming period from 1910 to 1940 (see page 88 of *Unsettled*). If the models cannot accurately replicate what has happened in the past, should we blindly trust them to predict the future? Reason says no. When models we create to forecast the future cannot accurately re-create past performance, we should certainly understand that the *Science* is NOT *Settled*. As professionals trained to think critically, we should avoid perpetuating the false narrative that the science is settled.

I understand that, as a society, we should be concerned about the changing climate and how it might affect us. As engineers, we will be involved in solving problems associated with climate change. But, given the actual state of our *knowledge*, it is a very reasonable thing to debate how we should spend our limited resources. This could impact our recommendations to our clients and how our professional organizations prioritize the development of guidelines. I would suggest that we presently focus on adapting to the observed changes (which is what mankind has done for the past many millennia) rather than focusing on speculative responses that might – or might not – affect how the climate changes. Carbon sequestration, elimination of fossil fuels, and carbon taxes are examples of those speculative things. And those speculative things often come at a significant cost to society, with the most impact on the poorest of us.

For those interested in the current state of adaptation, see the November 5, 2022, edition of *The Economist*. Contained in that issue is a special report on Climate adaptation, which discusses several different issues related to how society can and will adapt to the changes that are certain to occur in our climate. One key component of almost all approaches to adaptation is the need for engineers.

Here's hoping that this article engenders some much-needed open discussion regarding this critical issue.▪

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