

■ **Although I enjoyed** most of Steve Sherwood's article on science controversy, I was a bit surprised to read a job at geologists that sounded more like what I'd expect to hear from physicist caricature Sheldon Cooper of CBS's *The Big Bang Theory* than from an article in a serious publication. Sherwood suggests that traditional geologists "emphasize empiricism and classification" and "consider ab initio theoretical approaches to be hopeless." (A more derogatory phrasing I've heard from other physicists is that "geology is just stamp collecting.") Especially since the advent of plate tectonic theory, academic geology has in fact emphasized testing hypotheses about Earth processes and not simple classification.

Sherwood's claim that geologists are as skeptical about global warming as the general public is also misleading. The article he cites¹ does note that only 47% of 103 surveyed economic geologists—those who study mining, oil and gas, and so forth—agree that "human activity is a significant contributing factor in changing mean global temperatures," but the same survey showed that among 1749 publishing geoscientists surveyed, 89% agree.² The resistance of some geologists to accept anthropogenic warming may be related to their financial reliance on the fossil-energy industry, but aspersions on geologists' use of the scientific method are not warranted.

References

1. P. T. Doran, M. K. Zimmerman, *Eos Trans. Am. Geophys. Union* **90**(3), 22 (2009).
2. M. K. Zimmerman, "The consensus on the consensus—An opinion survey of Earth scientists on global climate change," MS thesis, University of Illinois, Chicago (2008).

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■ **Sherwood replies:** The letters here in response to my article raise legitimate points but also propagate some common confusions.

Most important, Robert Adair, William Dickinson, and Ron Larson blur the distinction between the basic physical principles of global warming and the provision of dire forecasts or calls for action. My article was very specifically about the acceptance of the underlying physics of global temperature, not claims about specific consequences, which are arguably unpredictable, or about policy, which is a matter of judgment. As scientists we must hold this distinction and help oth-

ers to do so, because the essence of clear thinking on any difficult issue is to break it down into smaller pieces. It is one thing to claim that anthropogenic climate change is not worth addressing, but quite another to deny its reality or basis in physics. People's assessment of the evidence tends to be driven by their policy views rather than the reverse.¹ This inversion of reason may not be new, but it is certainly not good for science.

The description Adair cites by Irving Langmuir and Robert Hall of the hare-brained ideas championed by some self-deluded physicists is indeed appropriate—but the true parallel is with the ideas floated by climate contrarians. Compare, for example, the enchanting early-1900s story of "N rays" with the current idea that the Sun has caused warming, perhaps by modulating cosmic-ray fluxes: True solar believers ignore the absence of any recent trend in observed solar activity, rely on data correlations that fail proper significance tests, and invoke mysterious amplification factors to enable tiny changes in solar irradiance to compete with the far larger and directly measurable power input by added greenhouse gases. They do not explain where the greenhouse gas power input is going if it is not heating the planet, and they must dismiss as coincidence its accord with the rate of accumulation of enthalpy in the world's oceans. That may exceed the worst of Langmuir and Hall's examples of hope over common sense.

Moreover, Adair is wrong in asserting that such flubs met with "similar receptions" to ideas now heralded. The way to find common sense is to look for assessments that are common among those who should know. Langmuir and Hall point out that the harebrained ideas were never accepted by a clear majority of experts and eventually by only a handful who could not let go. That is also the trajectory of contrarian theories of climate. Unfortunately, there are always rewards for telling people what they want to hear, so the handful of expert contrarians will not disappear anytime soon and may even grow for a while. A couple of them may be highly respected, but respect has never conferred immunity to self-delusion or opportunism.

As for successful predictions quite reasonably requested by Sergio Rojas, the warming forecast in 1990 in the first report² by the Intergovernmental Panel on Climate Change remains on target both in terms of global mean and approximate geographical patterns; we have also seen stratospheric cooling

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and a host of other long-predicted side effects. Given the stochastic behavior of the system, one cannot ask for much more without waiting several more decades for the warming signal to grow bigger. Albert Einstein's prediction of light bending may have been a lot more precise, but neither prediction put skepticism to rest at the time, no matter how conclusive it may look in hindsight.

I agree with Adair that if no warming were to occur over a 20-year period, experts would have some explaining to do, but currently there is no sign of that happening. He questions the statistical significance of warming since 1998, but that is a red herring; trends over a mere decade are seldom significant no matter what climate is doing. One must look over longer periods.

To Nicholas Van Buer I say that I meant no slight against geologists—or geoscientists, a category he mentions that also includes geophysicists. I spent many years working alongside geologists and am greatly impressed by how they approach and solve such complex puzzles. But those problems do tend to engender in geology a different approach from that favored in physics, where the systems studied are simpler. Each approach has its advantages and its blind spots. In a way I was defending the physics approach, which I suspect is the less intuitive for most people and easy to belittle if not understood.

References

1. N. Klein, *Nation*, Nov. 2011, available at <http://www.thenation.com/article/164497/capitalism-vs-climate>.
2. J. T. Houghton, G. J. Jenkins, J. J. Ephraums, eds., *Climate Change: The IPCC Scientific Assessment*, Cambridge U. Press, NY (1990).

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■ **Somerville and Hassol reply:** We appreciate the comments by all the writers but must take exception to several statements by Robert Adair, whose expertise famously ranges from particle physics to baseball but clearly does not include climate science. In examining the hoary claim by climate contrarians that global warming stopped in 1998, he may indeed have “looked at the data.” However, he obviously did not learn the research literature. The global mean surface temperature record displays both strong natural variability and a long-term warming trend, and decadal

periods are demonstrably inadequate for evaluating long-term trends. Nineteen ninety-eight was a strong El Niño year, hence it was unusually warm, and using that year as a starting point for computing a meaningful trend is cherry picking.

Recent data are fully consistent with the expected warming trend of about 0.2 °C per decade. Every year since 2000 has been warmer than the 1990s average, every year of the 1990s was warmer than the 1980s average, and the 1980s were the warmest decade on record until then.¹

Adair also inappropriately dismisses a warming of 0.8 °C as equivalent to moving 50 miles southward in the central US. Confusing local and global temperatures is nonsensical, and a global warming of about 8 °C is not at all like moving 500 miles. It is like the difference between an ice age and an interglacial period.

In another bizarre misrepresentation, Adair compares our list of terms to “sales jargon” that is “supposed to incite the populace.” In fact, our list of terms that mean different things to the public than they do to scientists has been widely cited and praised, because so many people have encountered the failure to communicate that can result from the different meanings. The only thing we’re selling is improved clarity of communication that can help bring science to its rightful place in decision making.

Adair consistently misrepresents our positions and those of the broader climate science community. The science we outline is entirely consistent with the 2007 Fourth Assessment Report from the Intergovernmental Panel on Climate Change (IPCC). Adair says that “some very good scientists do not find the necessary feedbacks plausible and conclude that the increased [carbon dioxide] cannot be responsible for most of the perceived warming.” He fails to say that almost all those dissenting scientists are, like himself, neither credentialed experts nor active researchers in climate science. The IPCC report concludes that most of the warming is very likely (greater than 90% probability) due to human-caused increases in greenhouse gas concentrations. The evidence for carbon dioxide-induced warming amplified by feedbacks in the climate system, such as increased water vapor, is abundant and strong.

Adair also appears to misunderstand the physics of climate models when he claims that their projections of the future are based on the past

150 years of observational data. He also misreads the projections to suggest that atmospheric CO₂ concentrations can climb to 1250 ppmv by 2100 and still result in temperature increases that would be “innocuous or even beneficial.” As the IPCC report on impacts² and many other assessments³ have shown, the 0.8 °C rise we’ve experienced to date is already causing impacts, most of which are not beneficial. Future impacts are projected to be more severe.

We do not, as Adair says, “argue” for a “radical” view. Rather, we simply explain that if governments decide on a certain limit for future temperature rise, as they have with the 2 °C target, then science can inform us of the emissions limits required to meet that goal. As we demonstrate in our article, Mother Nature herself thus imposes a time scale on when emissions need to peak and then begin to decline rapidly. The urgency is not ideological at all, but rather is due to the physics and biogeochemistry of the climate system. Advances in climate science have led to a profoundly deeper understanding of human-caused climate change. The impressive scientific story is certainly worth communicating well.

References

1. For a summary suitable for nonspecialists, see <http://www.realclimate.org/index.php/archives/2009/10/a-warming-pause>. See also S. A. Rahmstorf et al., *Science* **316**, 709 (2007), doi:10.1126/science.1136843, available online at http://www.pik-potsdam.de/~stefan/update_science2007.html (updated figures with link to *Science* article).
2. M. L. Parry et al., eds., *Climate Change 2007: Impacts, Adaptation and Vulnerability—Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge U. Press, New York (2007), available at <http://www.ipcc.ch>.
3. See, for example, US Global Change Research Program, *Global Climate Change Impacts in the United States*, Cambridge U. Press, New York (2009).

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Exploring the art of science

Tom Crouch's article, “NASA art: 50 years of exploration” (PHYSICS TODAY, August 2011, page 42), was very enjoyable. Though I'm now retired,