PROFILE

Profile of Michael E. Mann

Matthew Hardcastle, *Science Writer*

"I've sometimes referred to one's scientific career as a sort of random walk," says Michael E. Mann, referring to a mathematical model. "There have been a number of significant junctures where I shifted direction, but it feels like it's been leading somewhere." In 1999, Mann was the lead author on an article (1) featuring what is now widely known as the "hockey stick graph." The graph traces the average annual temperature of the Northern Hemisphere, which was largely stable for the last 1,000 years before climbing dramatically to the present as a result of human-caused climate change. Mann, who was elected to the National Academy of Sciences in 2020, is a professor of atmospheric science at Pennsylvania State University. In his Inaugural Article (2), Mann reviews how climate science has evolved in the past two decades and identifies critical work that remains to be done.

From Physics to Climate

Mann grew up in Amherst, Massachusetts, where his father was a professor at the University of Massachusetts. "My earliest memories are of being fascinated with basically how the world works and asking, sometimes annoyingly, the adults in my life questions to which they often didn't have the answers," Mann says. In his early teens, Mann's interest in science was further piqued by *Cosmos*, the renowned public television series hosted by Carl Sagan.

Mann attended the University of California, Berkeley and double-majored in applied math and physics. "I was always more of a theory, rather than an experiment, person," Mann says. He went on to Yale University to pursue research in theoretical condensed matter physics and solid-state physics, obtaining Master of Science and Master of Philosophy degrees in physics in 1991. However, 2 years into a PhD program in physics, Mann's interest began to wane. The industrial applications of solid-state devices did not continue to appeal, despite initially inspiring his curiosity.

"I either saw the light or lost my way, depending on your perspective," Mann says. While flipping through the pages of a Yale University catalog, he chanced upon professor Barry Saltzman, who was using math and physics to understand Earth's climate system. "That sounded fascinating to me. It was an area where I could bring the skills and training that I had acquired and achieved to work on a big picture problem." Mann met with Saltzman, and the two hit it off. After spending a summer doing research with Saltzman, Mann switched to the department of geology and geophysics, going on to earn his doctorate in 1998.

The Hockey Stick

Mann was initially interested in studying natural climate variability and answering the question of whether there are internal oscillations in the climate system on decadal timescales. While he was still finishing his doctorate, he started a postdoctoral position at the University of Massachusetts, Amherst, a kind of homecoming. He began a collaboration with Raymond S. Bradley, also at Amherst, after Bradley had a chance encounter with Mann's parents at a wine-tasting event.

Mann's postdoctoral research involved constructing a coupled ocean–atmosphere model and applying statistical methods to historical and paleoclimate data. Data about Earth's past climate is reconstructed from proxy records, which include tree rings and ice cores. The now-famous hockey stick graph, which tracks average temperatures in the Northern Hemisphere over the past 1,000 years, was one of the results of this research, but Mann did not initially consider it to be a particularly important finding. "In a sense, averaging over the entire Northern Hemisphere is the least scientifically interesting thing you can do, because you're averaging away interesting patterns that can tell you about these volcanic influences and El Niño and everything else."

Although the public discussion around human-caused climate change was controversial at the time, it had already been largely accepted as a reality in the scientific community since at least the mid-1990s. There was a large volume of evidence, and several detection and attribution studies had been published. However, the hockey stick graph was uniquely suited to grab the attention of scientists and the general public alike.

"The hockey stick was just this curve," Mann says. "It spoke for itself, in a sense. It spoke to the profound impact that we were having on our climate, and because of that, I think, it commanded even more attention than

This is a Profile of a member of the National Academy of Sciences to accompany the member's Inaugural Article, e2112797118, in vol. 118, issue 39.
Published September 29, 2021.

Michael E. Mann. Image credit: Joshua Yospyn (photographer).

some of those earlier, more technical studies. And it certainly garnered the attention of the critics who saw it as a real inconvenient piece of evidence, because it really did have the potential to convince the public and policymakers."

Mann, who was not yet press-savvy at this point in his career, suddenly found himself on national evening news programs. He was chosen as a lead author on the Intergovernmental Panel on Climate Change (IPCC) Third Assessment Report (3), published in 2001. The hockey stick graph was featured in the report's summary. In 2007, the IPCC and former US vice-president Al Gore were jointly awarded the Nobel Peace Prize for their efforts to educate about and inspire action on human-caused climate change (4).

Mann's sudden rise to national prominence also exposed him to attacks from groups with a vested interest in discrediting the science of climate change, including the fossil fuel industry and politicians. "That forced me out of the laboratory into the public sphere, to defend myself from these attacks." Ultimately, Mann came to see this as an opportunity to engage with the public discourse about climate change. He looked to other scientists-turned-communicators for inspiration, Carl Sagan chief among them.

"It's not a role that I signed up for," Mann says, "but I've come to embrace it, because I can think of no greater privilege than being in a position to inform the societal conversation about, arguably, the greatest challenge that we face as a civilization." In addition to his ongoing research, Mann has authored several books for the general public and continues to do public outreach.

Beyond the Hockey Stick

In Mann's Inaugural Article (2), he summarizes the lessons learned in the two decades since the hockey stick was published. Coming full circle to his initial climate research, Mann highlights the importance of understanding natural variations in climate to interpret the effects of rising temperatures.

The Atlantic Multidecadal Oscillation is a term Mann himself coined. The term refers to a supposed natural, internal oscillation in tropical Atlantic warming and cyclone activity on the timescale of 50 to 70 years. Belief in this oscillation has become widespread, and some skeptics have tried to use it to dismiss the reality of climate change. However, Mann argues that observations and simulations no longer support the existence of this phenomenon. He suggests that this effect is an artifact in the data, produced by the coincidental spacing of explosive volcanic eruptions and the resulting cooling in past centuries.

"The lesson there is [that] you follow where the science takes you, even if it takes you to the point where you are refuting your own previous work. It's an uncomfortable place to be, but you have to be prepared to do it, if that's where the science takes you," Mann says.

Mann also highlights other important discrepancies between simulation and data. For example, major

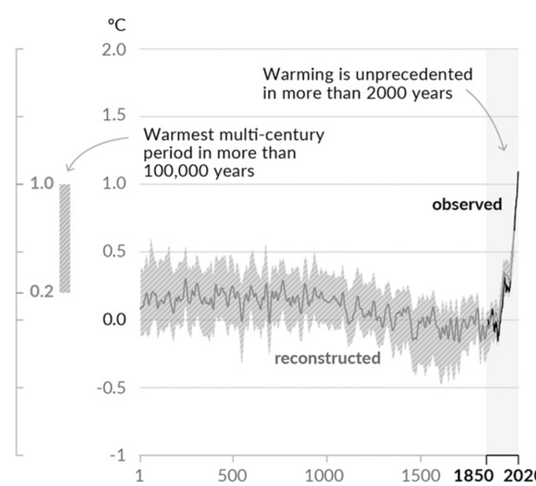

Fig. 1. Changes in global surface temperature reconstructed from paleoclimate archives (solid gray line, 1 to 2000) and from direct observations (solid black line, 1850 to 2020), both relative to 1850 to 1900 and decadally averaged. The vertical bar on the left shows the estimated temperature (very likely range) during the warmest multicentury period in at least the last 100,000 years, which occurred around 6,500 years ago during the current interglacial period (Holocene). The Last Interglacial, around 125,000 years ago, is the next most recent candidate for a period of higher temperature. These past warm periods were caused by slow (multimillennial) orbital variations. The gray shading with white diagonal lines shows the very likely ranges for the temperature reconstructions. Reprinted with permission from ref. 5.

https://doi.org/10.1073/pnas.2116275118

volcanic eruptions are generally expected to produce widespread cooling. However, proxy data from tree rings has sometimes recorded only modest cooling after major eruptions. Mann suggests that years with particularly low temperatures may result in no growth at all for some trees, thus producing no record for that year.

Another consideration is how data from a colder Earth is interpreted and applied to the current hothouse climate. "We've probably got to go back 8 million years to find a natural time when CO_2 concentrations were as high as they are now," Mann says. Data from the distant past becomes sparse. However, data from the Common Era is more readily available, but most of that time period has been cooler than today and cooler than our future is likely to be.

"The climate mechanisms that may be relevant in a hothouse world are fundamentally different from some of the mechanisms that are most relevant to an icehouse world," Mann says. For example, permafrost melting and glacier thawing only occur above a certain temperature threshold and may produce a feedback effect not present during colder periods of Earth's history.

These discrepancies are relevant for trying to predict equilibrium climate sensitivity, which is the expected warming that will result from a doubling of atmospheric CO_2 over preindustrial levels. Mann says the current consensus on climate sensitivity is warming between 2 and 4.5 °C. Global temperature increases above 2 °C are expected to result in catastrophic climate change. While studies have attempted to refine the lower range of climate sensitivity estimates, Mann cautions scientists against attempting to place an upper limit on future warming. The feedback effects of a hothouse climate might produce even higher temperatures than expected from paleoclimate data alone.

Other open questions include the effects of climate change on ocean circulation. Mann says there is some evidence that the North Atlantic conveyor belt current is slowing down, which could have profound effects on Europe and North America. El Niño and La Niña are naturally occurring climate patterns in the Pacific that influence global weather. Climate change is likely to affect these patterns, but it is not yet clear how. If the climate comes to resemble either a permanent El Niño or a permanent La Niña pattern, it could have ramifications for extreme weather events, such as hurricanes and heatwaves.

Urgency and Agency

Mann has seen the initial denialism over human-caused climate change subside in recent years, as the reality of global warming has become apparent. However, interests opposed to regulations intended to curb climate change have turned to increasingly subtle tactics, espousing the narrative of personal responsibility to deflect blame. While Mann says everyone should do their part to reduce their own carbon footprint, governments should be held accountable for enacting large-scale changes, such as subsidizing renewable energy and implementing carbon pricing.

"The numbers are unforgiving, and climate modelers have done the calculations," Mann says. However, he argues there is still time to act to avert the worst effects of climate change. "There's urgency, but there's agency. We can do this. We must do this, because it's not just about us. It's about what sort of planet we want to leave behind for our children and grandchildren."

1 M. E. Mann, R. S. Bradley, M. K. Hughes, Northern hemisphere temperatures during the past millennium: Inferences, uncertainties, and limitations. *Geophys. Res. Lett.* **26**, 759–762 (1999).

2 M. E. Mann, Beyond the hockey stick: Climate lessons from the Common Era. *Proc. Natl. Acad. Sci. U.S.A.*, 10.1073/pnas.2112797118 (2021).

3 R. G. Watson *et al.*, Eds., *Climate Change 2001, Synthesis Report: Contribution of Working Groups I, II, and III to the Third Assessment Report* (IPCC, 2001).

4 NobelPrize.org, The Nobel Peace Prize, 2007, https://www.nobelprize.org/prizes/peace/2007/summary/ (2007).

5 V. Masson-Delmotte *et al*, Eds., "2021: Summary for Policymakers" in *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change V.* (Cambridge University Press), in press.