Disillusionment with climate models

Predicting Our Climate Future: What We Know, What We Don't Know, and What We Can't Know, David Stainforth

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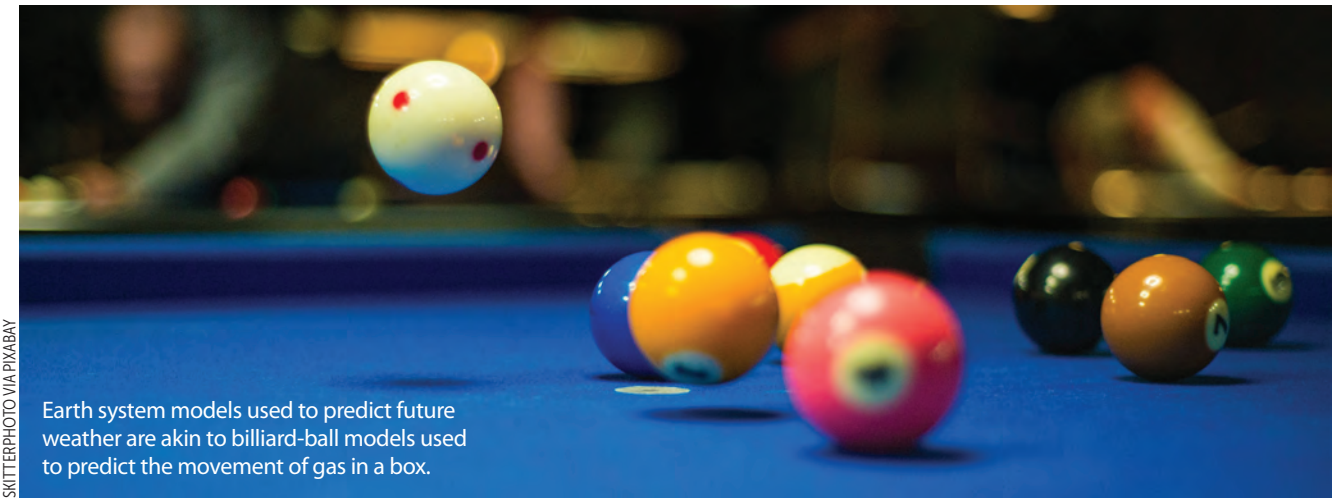

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Earth system models used to predict future weather are akin to billiard-ball models used to predict the movement of gas in a box.

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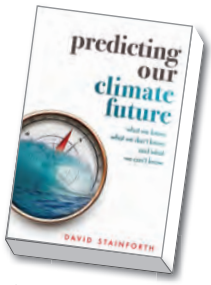

Predicting Our Climate Future
What We Know, What We Don't Know, and What We Can't Know
David Stainforth
Oxford U. Press, 2023. $24.95

David Stainforth's ambitious book *Predicting Our Climate Future: What We Know, What We Don't Know, and What We Can't Know* spans a vast territory, starting from the philosophical and scientific underpinnings of supercomputer climate models to an assessment of the economic, social, and policy implications of climate change. It is an insider's reflection on 30 years of climate modeling and policy.

Opening chapters cover dynamical-systems concepts, including probability, deterministic chaos, and phase space. To achieve that without equations—and to lighten the prose—Stainforth uses detailed analogies, such as humorous images of kettles, grandfather clocks, tennis balls, and polyhedral dice, with some more successful than others.

Stainforth introduces the reader to today's supercomputer Earth system models. Those are souped-up weather models that might, for example, predict 20 cm of snow in Montreal on the morning of 18 December 2099. Since Earth system models are sensitively dependent on small-scale initial conditions, they are chaotic and interpreted probabilistically. The Earth system models used in the assessment reports of the Intergovernmental Panel on Climate Change (IPCC) currently have hourly resolutions and must be averaged over 100 000 time steps to yield the reports' decadal projections.

Statistical physicists may be troubled that supercomputers are tasked with calculating so many details that are already known to be irrelevant, yet for Stainforth, the real problems lie elsewhere. He cites three: poorly known macroscale initial conditions, such as today's climate state; tuning bias; and the status of multimodel ensembles.

If an Earth system model is akin to the billiard-ball model of a gas in a box, for which the aim is to predict the positions and velocities of the balls at some later time, then the macroscale initial conditions are the gas's temperature, density, and other variables. Today's poorly constrained macro-initial climate state invites compounding uncertainties in the chaos-induced probabilities.

Tuning bias is a consequence of the Earth system model itself being ill defined. It arises because of many numerical approximations in the underlying physics. In his book, Stainforth describes a numerical experiment on an Earth system model that has 21 such parameters, and in principle, each parameter must be reevaluated after any model updates or changes.

The IPCC's scenario-based predictions use multimodel ensembles compiled from approximately 40 Earth system models, each of which was built by a different team but uses the same "scenarios" or assumptions about future human behavior, especially about future greenhouse gas emissions. The uncertainty bounds—the confidence limits—in the IPCC's multimodel-ensemble "projections" are simply quantifications of the differences between the different Earth system models.

As the book progresses, Stainforth's disenchantment with current climate models becomes evident. The classic Earth-system-models approach is indeed in crisis, and Stainforth is in growing company. He, along with colleagues, suggests replacing probabilistic climate projection frameworks with subjectively evaluated sequences of events, or storylines. Other disenchanted colleagues variously prefer using artificial intelligence or machine learning to make projections.

To understand the disenchantment, one needs to look at a key climate parameter: the amount that the temperature will increase following a doubling of atmospheric carbon dioxide. Although for decades the uncertainty has been fairly large, the experts and the models had always been closely aligned. Now experts have converged around a much smaller temperature range, yet the members of the IPCC's new multimodel ensemble are—for the first time—diverging

from each other, yielding a wider temperature range and an increased uncertainty. Today the experts are confident that they know better than the models.

The last part of the book discusses the human side of climate change; determining future warming is only the first step in dealing with the climate crisis. We need to evaluate the social, economic, and environmental consequences of a warmer planet. Stainforth summarizes some of the contentious results of mainstream economists; he not only underlines the wide divergences among them but also stresses how even a small change in the predicted warming drastically changes the damage estimates.

In *Predicting Our Climate Future*, Stainforth lists many factors for the divergences, perhaps the most important of which is the choice of discount rate, which is used to express the costs of future climate damage in terms of today's currency. A typical discount rate of 6%—advocated by the economist William Nordhaus—would put the cost of avoiding $200 trillion of climate damage in the year 2100 at a mere $2 trillion today. If we really care for our children, we should instead follow Nicholas Stern in his 2006 report on the economics of climate change and use a much lower rate: Stainforth discusses a discount rate of 0.1%, while Stern used an average rate of 1.4%. Using the latter rate yields $72 trillion today, comparable to the global GDP, and it led to Stern being accused of making "fear-mongering arguments" in a *Wall Street Journal* editorial.

Stainforth does an admirable job navigating the wide-ranging and technically demanding material, yet statistical physicists may have reservations. Why forecast the weather to the year 2100 when the goal is a decadal average? Why care about the positions and velocities of the particles in a box if all you want is the macroscopic pressure or temperature? Indeed, an entire historical strand of fluid mechanics and atmospheric sciences—turbulence theory—is dedicated to elucidating the relevant higher-level statistical laws, and that neglected strand has already started to evolve with new stochastic models that substantially reduce uncertainties. Still, for those interested in an introduction, Stainforth's book is a useful place to start.

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NEW BOOKS & MEDIA

The Six

The Untold Story of America's First Women Astronauts

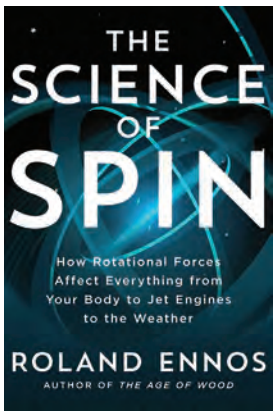
Loren Grush
Scribner, 2023. $32.50

In 1978 NASA accepted six women into its previously all-male astronaut corps: Sally Ride, Judy Resnik, Kathy Sullivan, Anna Fisher, Margaret "Rhea" Seddon, and Shannon Lucid. *The Six* tells the inspiring story of the women's journeys up to entering the astronaut program, their experiences once they were admitted, and the pioneering missions that made them the first US women to fly into space. According to the author's note, as part of her research, science reporter Loren Grush conducted more than 100 hours of interviews, consulted archival documents, and reviewed audio and video footage of old interviews and press conferences. The result is a vivid, blow-by-blow account of a groundbreaking period in history. —CC

The Science of Spin

How Rotational Forces Affect Everything from Your Body to Jet Engines to the Weather

Roland Ennos
Scribner, 2023. $28.00

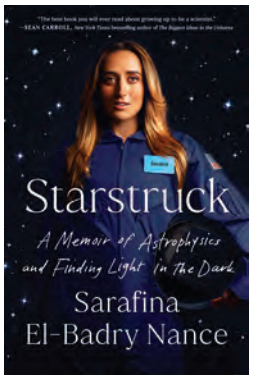


In this popular-science book, biologist Roland Ennos sheds light on a fundamental physics principle that he claims has not received the attention it deserves. As Ennos points out, the science of spin "pervades" the world around us. Spin helped form the universe, made Earth habitable, allows humans to walk upright, and is integral to machinery and technology. Yet most people don't really understand how it works. To explain the mechanics of rotation, Ennos eschews mathematical formulas and equations in favor of more intuitive physical explanations of the workings of the universe, human beings, and the machines we've created. The result is a highly approachable book for general readers and scientists alike. —CC

Starstruck

A Memoir of Astrophysics and Finding Light in the Dark

Sarafina El-Badry Nance
Dutton, 2023. $29.00



Long fascinated with the stars, astrophysicist Sarafina El-Badry Nance presents a memoir that blends tales of her educational experiences and family life with observations about the universe. Growing up in Texas in the 1990s and 2000s with an American father and Egyptian mother, Nance battled racism, sexism, her parents' marital strife, and her own insecurities to pursue her dream of becoming an astronomer. But even after gaining entry to the graduate astronomy program at the University of California, Berkeley, she found that life had thrown her yet another curveball—she'd inherited her father's cancer gene, which prompted her to undergo a double mastectomy. Despite the heavy subject matter, *Starstruck* is engaging and inspirational. —CC PT