

science denial we have to understand what stories are unfolding in his [the denier's] head and where they come from."

As a historian of science, I welcome attempts to understand the present through history. One should, however, be careful with the use of universal categories that might easily be challenged, such as the word science (yes, singular) as we find it in the book. Crease's narrative seems to unravel as follows: Bacon invented how to institutionalize modern science, and people such as Galileo and Descartes had to fight against those who opposed an otherwise obvious need for such methods and institutions. After that, some thinkers—including Vico, Shelley, Husserl, and Arendt—helped shape the social authority of science with their valid criticisms of it.

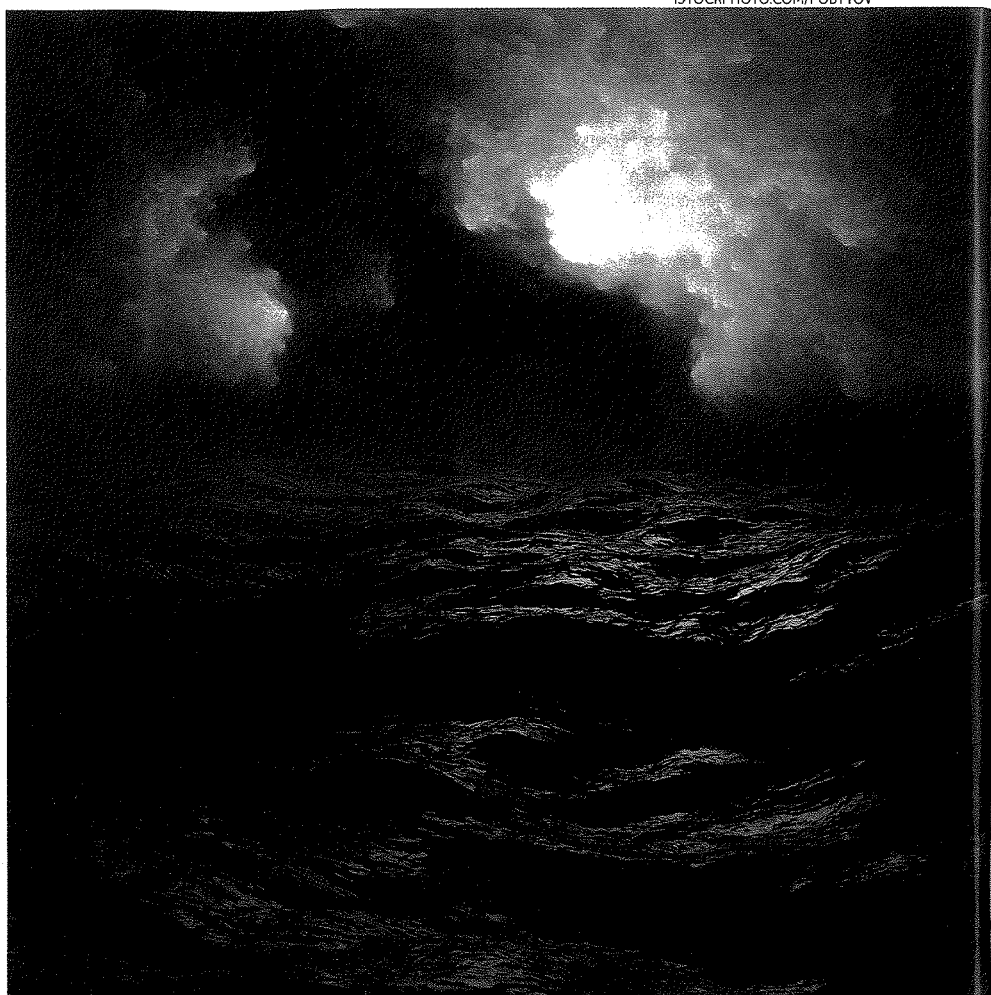
Meanwhile, members of the Inquisition, dictators, contemporary Trump supporters, and others have stubbornly or irrationally attacked the authority of science. I believe that the Manichean story is far too simple. I wonder, for example, if Crease would regard President Dwight Eisenhower's 1961 farewell address warning about the dangers of technocracy as antiscience.

Crease proposes as solutions a list of short-term and long-term policies, the most surprising being to demand that any person wanting to participate in the public sphere take a pledge for science. That sounds to me like a totalitarian attempt to expel criticism. Who would write and police that pledge? And how far could it go without becoming ideological rather than scientifically neutral? A diverse group of philosophers of science would probably never agree on a common text for the pledge. Perhaps we should leave the work of granting scientific citizenship to Comte and his positivist church in chapter 6 of Crease's text or to a new Atatürk in chapter 8.

Some long-term strategies that Crease suggests, including the emphasis on science education and nuanced historical accounts of how we got here, may indeed be helpful. And if done honestly, those strategies will prevent science from being used as a simplistic ideological catchword, which, at the end of the day, is what science deniers—and some self-appointed science promoters—do.

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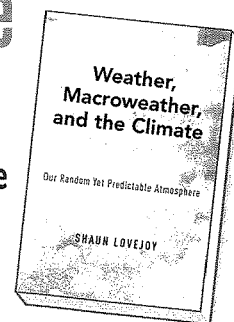
## An introduction to our chaotic atmosphere and climate

The geophysical community recognizes that the observational data they collect are incredibly complex. As temporal and spatial scales get larger, the fluctuations in the atmospheric and other Earth fields systematically increase or decrease. Such behavior occurs not only in climate dynamics but in seemingly unrelated fields such as geomorphology. A closer look reveals that complex signals are governed by statistical relationships that connect billions of structures over a wide range of time and length scales. The resulting quantifiable scaling laws capture the power law growth or decay of fluctuations. Lewis Fry Richardson first proposed the idea in the Richardson  $\frac{2}{3}$  law of turbulent diffusion.

**Weather,  
Macroweather,  
and the Climate  
Our Random Yet  
Predictable  
Atmosphere**

**Shaun Lovejoy**

Oxford U. Press, 2019. \$34.95



The ubiquitous nature of scaling laws is masterfully analyzed in *Weather, Macroweather, and the Climate: Our Random Yet Predictable Atmosphere* by Shaun Lovejoy. Recipient of the 2019 Lewis Fry Richardson Medal, Lovejoy has devoted his career to understanding scaling laws empirically and theoretically. In his book, he shows readers from all back-

grounds the atmosphere from a new perspective. Although he places the discussion in a broader context, the main focus is on his research: In the late 1970s, he broke new ground on the statistical analysis of precipitation using monofractals. Lovejoy then covers the extension of those ideas to other turbulence-dominated domains in the 1980s and 1990s using multifractals. Subsequently, multifractals have proven to be important for phenomenological descriptions and models of highly turbulent processes in the physical sciences and marine biology.

Lovejoy explains that generations of scientists who studied turbulence suspected that many vortices, cells, and structures could be explained by high-level statistical laws. Chaos theory characterizes the universal behavior underlying seemingly random dynamical systems. But the underlying mathematics proved difficult, largely because most of the activity is in tiny, violently active areas that are buried in a hierarchy of structures. Lovejoy emphasizes that scale-dependent stratification caused by gravity poses an additional obstacle to the application of turbulence theory to the atmosphere.

*Weather, Macroweather, and the Climate* explains in simple terms the concept of atmospheric variability, from millimeter to planetary scales and from milliseconds to billions of years. Five years ago, researchers found that classical approaches had underestimated the variability by a quadrillion (a million billion).

In the most important chapter, Lovejoy explains his empirical observation of low-frequency “macroweather” at intermediate time scales of about 0.1 to 100 years, in between the fast time scales of conventional weather and the slow time scales of climate. He clearly describes how the familiar weather-climate dichotomy becomes the weather-macroweather-climate trichotomy, and he details how scientists can exploit the long-term memory of the atmosphere-ocean system to make accurate monthly to decadal forecasts. Lovejoy illustrates that applying the scaling approach to the Anthropocene—the current geological period of man—can reduce the large uncertainties in current climate projections out to 2050 and 2100.

The author asks and answers the fundamental question, What is climate? He

also addresses Richardson’s basic questions, Does the wind have a velocity? and How big is a cloud? Through his answers, Lovejoy explains why the fractal dimension of atmospheric motion is  $D = 23/9 = 2.555 \dots$ , which is larger than the  $D = 2$  flat value that theoreticians have predicted but smaller than the usual  $D = 3$  volume-filling value. He also shows that Mars is our statistical twin and why that shouldn’t surprise us, and he explains how the multifractal

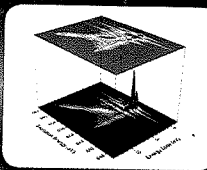
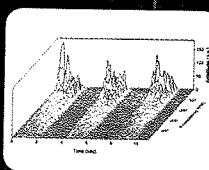
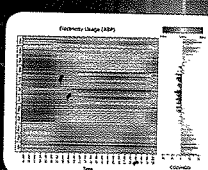
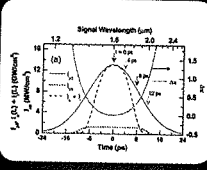
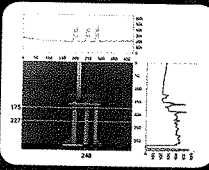
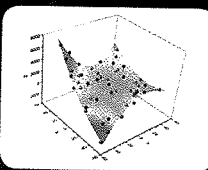
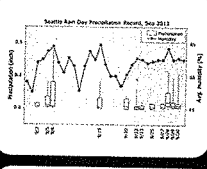
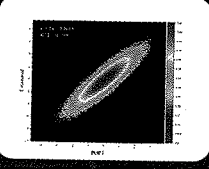
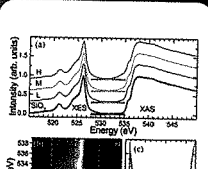
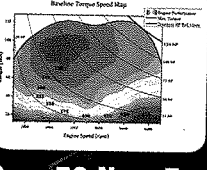
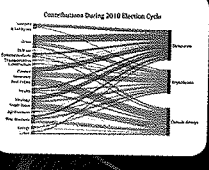
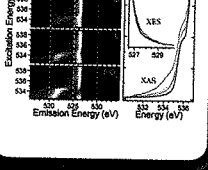
butterfly effect causes extreme events.

The book has more than a dozen boxed sidebars that provide even more information. Undergraduate and postgraduate students looking for an introduction to atmospheric modeling will not easily find one more readable than *Weather, Macroweather, and the Climate*.

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