A Formula to Keep the Science Flame Burning

James Hansen **08 July 2025**

Why is the Trump Administration trying to kill a small space science institute in New York City? Explanation begins with Galileo's method of scientific inquiry and ends with the role of special interest money in the United States government.

Galileo improved the telescope, allowing clearer observations of the planets and the Sun. Galileo differed from his peers, as he was unafraid to challenge authority. He claimed that the world should be understood based on observations, and he spoke directly to the public. He obtained philanthropic support for his observations and openly described the conclusion that Earth was not the center of the solar system – Earth revolved around the Sun.

Implications of Galileo's approach rattled the establishment. Galileo was opposed not only by the Catholic Church, but by many professors who did not fully understand Galileo's work and were reluctant to support a heretical viewpoint. At his Inquisition, Galileo recanted his views, to save his life. He could wait for history to vindicate him; the Scientific Revolution was beginning.

Science research and the primacy of observations were well advanced by October 1957 when the Soviet Union launched Sputnik 1, the first human-made Earth satellite. The United States responded by forming NASA in 1958 and supporting universities to develop space scientists. I benefitted from that support and, as a 25-year-old post-doc in February 1967, drove with great expectations from Iowa City to New York City, pulling over only once for a few hours of sleep, my destination being the NASA Goddard Institute for Space Studies (GISS) on the edge of the Columbia University campus.

GISS attracted scientists from around the world to carry out space science research, as described in The Universe on a Scratch Pad.[1] Patrick Thaddeus built a microwave telescope on the roof of GISS, which he used to discover numerous molecules in space, survey the molecular Milky Way, and help revolutionize understanding of the interstellar medium and star formation. In this citadel of research, I worked with Henk van de Hulst, the world-leading expert on light scattering, and led a team that developed an instrument for the Pioneer mission to Venus to investigate the veil of Venus, which shrouds Earth's nearest neighbor. We measured the properties of Venus aerosols – fine airborne particles that turned out to be sulfuric acid – more precisely in the 1970s than aerosols on Earth are measured today.

What is the justification for such a small laboratory? Robert Jastrow, the first GISS director, described the "GISS formula" for research in cooperation with nearby universities, including Columbia, New York University, and the City University of New York. The formula put equal emphasis on observations – the foundation of science – and theory. The small added cost of location in an urban setting was justified by the gain from working with top-notch academia, as well as the proximity of national media to help promulgate scientific progress. Indeed, the GISS formula actually limited costs by employing only a small number of government scientists, along with students, post-docs, and university research associates.

The GISS formula has other merits: independent thinking and ability to rapidly change research focus. For example, as changes of Earth's ozone layer emerged in the 1970s, it became clear that our home planet was more interesting and important than other planets. I began compiling Earth

observations, including global temperature, and focused my research group on development of a global model for computer simulation of climate change on Earth.

In 1982, soon after I was appointed to succeed Jastrow as GISS director, I was instructed to move GISS to the main Goddard center, which housed about 10,000 employees in suburban Maryland. The GISS formula would have been lost. Thus, we refused to go, but we survived in New York with reduced government funding. In this setting, we investigated climate change with equal emphasis on (1) paleoclimate, the history of climate change, (2) global climate modeling, and (3) observations of ongoing climate change. Based on this multi-faceted research approach, I could testify to Congress in 1988 with a high degree of confidence that the world had entered a period of global warming driven by human-made changes of Earth's atmosphere.

In 1989, Congress approved a multi-billion-dollar NASA "Mission to Planet Earth" to study global change. We GISS scientists proposed that the mission include small satellites for crucial climate measurements, especially of atmospheric aerosols and their effect on clouds. Aerosols increase reflection of sunlight to space, thus causing global cooling that partly offsets warming from increasing carbon dioxide and other greenhouse gases. Unfortunately, our proposal was viewed by NASA management as a threat to their larger satellites,[2] rather than a complement.

We persisted in advocacy of small satellites for decades, which resulted in renewed efforts to move GISS to Maryland. Again, GISS survived with further reduction of support, but with our perspective and intellectual integrity intact. Finally, after we had carried out additional research and aircraft measurements, we proposed a small satellite aerosol mission in cooperation with Pete Wordon, director of NASA Ames Research Center. When this proposal was blocked by the director of Goddard Space Flight Center, I retired from NASA.

In 2013, I initiated a broad research program, Climate Science, Awareness and Solutions, based entirely on public and philanthropic support, with cooperation of Prof. Jeff Sachs and Columbia University. Our research, based on paleoclimate, climate modeling, and modern observations, has produced results that challenge the climate dogma promulgated by the United Nations. The UN climate assessment (by IPCC, the Intergovernmental Panel on Climate Change) and the UN policy approach (defined by the Kyoto Protocol and Paris Agreement) are each so seriously flawed that they pose a threat to the future of young people and future generations.

The crucial science issue is climate sensitivity, which is a measure of global climate change in response to an imposed climate "forcing" such as a change of atmospheric greenhouse gases or aerosols. The common measure of climate sensitivity is the equilibrium (eventual) global warming in response to doubled atmospheric CO_2 (carbon dioxide). IPCC's best estimate of climate sensitivity (3 degrees Celsius, which is 5.4 degrees Fahrenheit) is based mainly on climate models, which have many uncertainties. Clouds are especially difficult to model because even a small cloud change affects Earth's reflectivity and energy balance. Thus, climate models, by themselves, cannot define climate sensitivity accurately.

Recent paleoclimate studies, especially improved data on global temperature during the last ice age[3] and on longer time scales,[4] show with more than 99 percent confidence that climate sensitivity is greater than IPCC's best estimate. Another, independent, indication of climate sensitivity is provided by satellite observations of a change in the amount of sunlight reflected by Earth. Earth has become darker during the past 25 years, as reflection of sunlight by clouds diminished. This cloud change provides an empirical measure of cloud feedback, that is, the

response of clouds to global warming. This amplifying cloud feedback confirms the high climate sensitivity derived from paleoclimate studies.

Explanation[5] of how IPCC underestimated climate sensitivity involves their reliance on climate models and their assumption that climate forcing by aerosols changed little in 1970-2005, as global temperature rose. However, even though global emissions of sulfur dioxide gas – the main cause of aerosol formation – were nearly constant in 1970-2005, emissions spread globally into more pristine air where emissions cause a larger climate forcing. Thus, aerosols had a cooling effect during 1970-2005. The upshot is that the average of climate models used by IPCC understated aerosol cooling and required a climate sensitivity of only 3 degrees Celsius to match observed warming. With more realistic aerosol cooling, larger climate sensitivity is required.

Thus, all three methods of analysis – paleoclimate, satellite observations, and climate modeling – indicate a climate sensitivity substantially higher than IPCC's best estimate of 3 degrees Celsius; our best estimate is 4.5 degrees Celsius.[5] The practical impact of this high climate sensitivity and aerosol forcing will be enormous. Aerosol cooling constrained global warming in 1970-2005, but since 2005 aerosols have been on decline globally, especially in China, Europe and the United States and since 2020 aerosols from ships have decreased due to regulations on the sulfur content of ship fuel. The result is acceleration of global warming. The global warming rate in the past two decades is nearly double the rate in 1970-2005.

Confirmation of our analysis is provided by precise monitoring of Earth's energy imbalance – the difference between absorbed solar radiation and heat radiation emitted to space. Because of the change from increasing aerosols in 1970-2005 to decreasing aerosols, Earth's energy imbalance – which is the drive for global warming – has doubled since 2005, from 0.6 to 1.2 watts per square meter averaged over Earth's surface. The latter value is equal to the energy in 800,000 Hiroshima atomic bombs per day (more than 500 per minute),[6] with 90 percent of this excess energy going into the ocean. Because of the massive size of the ocean, warming is gradual but relentless. In the absence of effective policy intervention, regional climate extremes will grow in coming decades, and there will be effects that are practically irreversible, such as rising sea level.

The climate threat is no reason to despair. However, to keep favorable climate we must account for world energy needs. Fossil fuels, the main source of gases that cause global warming, are an amazing energy source: a gallon of gasoline contains energy equal to that in 400 hours of labor by an adult. Fossil fuels have raised living standards in much of the world and provide 80 percent of the world's energy today. And energy demand is rising. Billions of people still strive to escape poverty. Fossil fuels are convenient and they will remain affordable as long as they are not required to pay their cost to society caused by their effects on human health and climate change.

Economists agree [7]that the main policy needed to phase down fossil fuel emissions is a gradually rising carbon fee.[8] With these funds distributed uniformly to the public, most low- and middle-income people receive more in the carbon dividend than they pay in increased energy prices, thus tending to lock in the policy. Governments also need to support modern nuclear power, which is available 24/7 to complement intermittent renewable energy. However, these policies, despite their low cost, are not well pursued in the United States by either major political party.

Our government's failure to address climate change effectively and the present administration's desire to exterminate a small science laboratory in New York City have a common explanation. I describe in Sophie's Planet[9] interactions with the government that expose a decades-long,

confounding, failure to take sensible, inexpensive, actions that would address energy needs and climate change. The problem is traced to special financial interests, especially the fossil fuel industry and the military-industrial complex, in affecting policies.

Corruption was recognized as a threat by our nation's founders, who provided us tools to fight it. Fossil fuel executives fund both parties to assure that a simple, honest, carbon fee is avoided, and they chortle at environmentalists who believe that subsidizing renewable energies will lead to phase out of fossil fuels. Militarism[10] tends to create permanent enemies and inhibit the global cooperation needed to address climate change. Soft power emanating from a democracy that functions as it is intended would be far more effective. It is possible to fix our democracy, I argue in *Sophie's Planet*, whether via a third party that takes no money from special interests or via bi-partisan legislation that constrains special interests, as Senator John McCain once advocated.

However, President Trump's attempt to close climate laboratories and halt collection of climate data is a new threat that warrants special attention. No executive order can destroy knowledge of the scientific method; in the worst case, institutes using the GISS formula can be reconstructed later. The greater threat is to science data, the essential fuel to keep the science flame burning. Even the Pope did not stop Vatican astronomers from observing the planets and thinking about their motions. Especially important are satellite data[11] for Earth's radiation balance and ocean measurements by deep-diving Argo floats,[12] with continuous measurements of both data sources required for absolute calibration of Earth's energy imbalance.[13]

Science itself is under threat today, in a way that I thought was no longer possible. Scientists who see and understand the threat must speak out. The next 5-10 years are crucial for policy decisions to define a course that provides energy to raise global living standards, while allowing climate policies that cool the planet enough to avoid locking in irreversible effects such as shutdown of the ocean's overturning circulation and large sea level rise.[14] These objectives require knowledge of ongoing climate change and the drives that cause change. We scientists must stand up against the forces of ignorance, fight for the collection of data, and work with young people to help them find a path to a healthy climate that benefits all humanity.

---

[1] The Universe on a Scratchpad, NASA film of the early 1960s.
[2] Hansen J Battlestar Galactica, Chapter 31 in *Sophie's Planet*, 10 draft chapters
[3] Seltzer AM *et al.* Widespread six degrees Celsius cooling on land during the Last Glacial Maximum. *Nature* **593**, 228-32, 2021
[4] Hansen J, Sato M, Simon L *et al*. "Global warming in the pipeline," *Oxford Open Clim. Chan.* **3(1)**, 2023, doi.org/10.1093/oxfclm/kgad008
[5] Hansen JE, Kharecha P, Sato M *et al.* Global warming has accelerated: are the United Nations and the public well-informed? *Environ.: Sci. Pol. Sustain. Devel.* **67(1)**, 6–44, 2025, https://doi.org/10.1080/00139157.2025.2434494
[6] A probably more useful comparison: global 1.2 W/m^2 is 32 times greater than humanity's energy use.
[7] Discussion of the Economists' Statement is at Hansen J Student leadership on climate solutions, 31 July 2020
[8] Hansen JE The eyes of climate change history are on Biden, Boston Globe, 8 August 2022
[9] Hansen J Sophie's Planet, preface and several draft chapters of book to be published by Bloomsbury.
[10] Wertheim S. How Many Wars Is America Fighting? The Gravel Institute, last access 6 July 2025
[11] Loeb NG *et al.* Satellite and ocean data reveal marked increase in Earth's heating rate, *Geophys Res Lett* **48**, 2021
[12] von Schuckmann K et al., Heat stored in the Earth system: where does the energy go? *Earth System Science Data* **12**, 2013-41, 2020
[13] Mauritsen T, Tsushima Y, Meyssignac B *et al*. Earth's energy imbalance more than doubled in recent decades. *AGU Advances* **6**, e2024AV001636, 2025
[14] Hansen J, Sato M, Hearty P *et al.* Ice melt, sea level rise and superstorms: evidence from paleoclimate data, climate modeling, and modern observations that 2 C global warming is highly dangerous. *Atmos Chem Phys* **16**, 3761-812, 2016