

The Lorenz Center

Massachusetts Institute of Technology



The Lorenz Center: A Fresh Approach to Climate Science

Founded by Professor Kerry Emanuel and Professor Daniel H. Rothman

Front cover photo: A researcher works with an ice core drill during the 2003 Antarctic Megadunes expedition. Photo courtesy of Ted Scambos & Rob Bauer, supplied by the National Snow and Ice Data Center, University of Colorado, Boulder.

Understanding and predicting global climate change is arguably the most complex scientific challenge ever faced by mankind.

The climate system consists of many interacting components, forming a highly nonlinear system of enormous complexity. Almost everything that has been proposed to affect climate—from microscopic aerosol particles to greenhouse gases to plankton to sea ice — seems to be important, so that the climate system does not appear to be dominated by a manageably small number of essential processes. Faced with this problem, efforts to simulate and predict climate are now largely based on the construction of complex computer models that reflect as accurately as possible the complexity of the real world. But the importance of climate change requires more than simulation and prediction; it requires improved understanding about how the Earth “system” works. If we fail to better understand the underlying system, we risk major errors in the prediction itself.

To address this problem, we suggest a renewed emphasis on fundamental questions. Surely the climate system is not so complicated that the only path to progress would be to create a digital world comprising each and every detail of the real world. After all, the laws of physics apply; stoichiometric balances cannot be violated; and modern research in ecology suggests that such physical and chemical constraints have profound consequences. Perhaps more convincingly, the regularity of many climate fluctuations in the geologic past suggests that the system can be understood without excessive complication.

But how so? We do not know, but we do know how to find out: by creating a new approach to climate science.

We believe that the most important step in creating a new science of climate is to tap into a pool of talent that is much larger than the pool from which today's graduate students and postdoctoral fellows are drawn. There is no lack of students interested in improving the world through climate science, and we already attract outstanding people. However, given the size of the challenge, there is a shortage of students with the backgrounds in physics, mathematics, chemistry, and biology that are desperately needed to advance theoretical understanding. At the same time, many very talented science students are understandably turned off by the existing state of climate science, which they perceive as intellectually uninteresting exercises in computer modeling rather than the pursuit of fundamental knowledge. To attract these students and young scientists, we need to portray climate science as the fascinating and hugely challenging scientific problem that it inherently is, and to provide them with a stimulating and rewarding environment in which to work. We need to make it not only possible, but desirable to explore completely new approaches to the problem; to take different tacks from the business-as-usual approach based on complex climate models.

Our idea, simply put, is both to attract the very best minds to climate science and to give them free reign to think creatively, unsaddled by the pressing practical demands of climate forecasting.



The Lorenz Center's John Carlson Lecture communicates exciting new results in climate science to the general public. The 2011 inaugural lecture featured Paul Hoffman, Sturgis Hooper Professor of Geology Emeritus at Harvard University. **From left to right:** John Carlson, the lecture's sponsor, Kerry Emanuel, co-founder of the Lorenz Center and Cecil and Ida Green Professor of Meteorology at MIT; Professor Hoffman; and Daniel H. Rothman, co-founder of the Lorenz Center and Professor of Geophysics at MIT.

We propose an emphasis on fundamental questions. Indeed, there is no shortage of grand intellectual challenges in climate science. Examples of grand challenges that would naturally attract interest range from purely physical questions to problems at the intersection of physics, chemistry, and biology:

- *Are two or more statistically stable climate states possible for the same climate forcing (solar radiation, atmospheric composition, configuration of continents)?* This is a problem of great inherent intellectual interest and potentially enormous practical consequences as well. At present, we do not know whether the real climate has multiple equilibrium states.
- *Why do CO₂ and temperature covary as they do in glacial cycles?* This striking relationship provides a fascinating window into the general problem of the control of atmospheric CO₂ and the carbon cycle, but we do not understand it. A related question is why CO₂ has been generally in decline over the past few hundred million years of earth history.
- *What accounts for the apparent long-term stability of biogeochemical cycles?* We are only beginning to understand the complex interaction of climate, chemistry, and biology, and it is not obvious that the known cycles are stable. Nor do we know the precise conditions under which they could become unstable.
- *What causes the deep meridional overturning of the ocean?* The ocean transports roughly half as much heat from equatorial regions toward the poles as does the atmosphere, yet the fundamental physics of the circulation are still not understood. After a century of work, scientists still find a comprehensive explanation of this circulation elusive, and the physics of this critical component of the climate system are not thought to be well represented in climate models. This is just one respect in which large-scale, complex modeling has proceeded without a clear understanding of the underlying physics, perhaps at its peril.

If we could imagine how an interdisciplinary group of imaginative scientists would approach such questions, we would not have founded the Lorenz Center. But we do know that breakthroughs in other disciplines often come from left field—from wholly different disciplines and approaches.

A particularly challenging aspect of the climate system is its combination of variability and structure, hallmarks of what are now called “complex systems.” Studies of such systems have revealed certain commonalities: extreme events, long-tailed non-Gaussian fluctuations, intermittency, emergence of extraordinary complexity from simple interactions, and a tendency of many such systems to exist in marginally stable states. Fundamental studies of the common features in such systems are at the vanguard of modern scientific research, yet they have played little role in modern climate science. These, or other approaches we have not imagined, may lead to rapid advances in our understanding of and ability to predict climate.

To better attract to the field the best scientists, capable of wholly innovative approaches, we must break with the intellectual and, to some extent, institutional culture that presently dominates climate science. To this end, we have established at MIT an advanced climate research center devoted to fundamental inquiry, and have named this new initiative the Lorenz Center after the late Edward N. Lorenz, the founder of modern chaos theory and an early contributor to theoretical climate science. Lorenz, a member of MIT’s faculty and a presence for over six decades, epitomized the qualities we seek: extraordinary creativity focused on fundamental aspects of natural phenomena. His work on chaos laid the foundation for one of the twentieth century’s greatest scientific advances. The center that bears his name seeks a similar impact in the twenty-first.

The goal of the Lorenz Center is to provide a small number of exceptional scientists with the freedom and resources to follow innovative high-risk paths toward a fundamental understanding of the mechanisms that influence Earth’s climate. Emphasis is on developing new theory and,

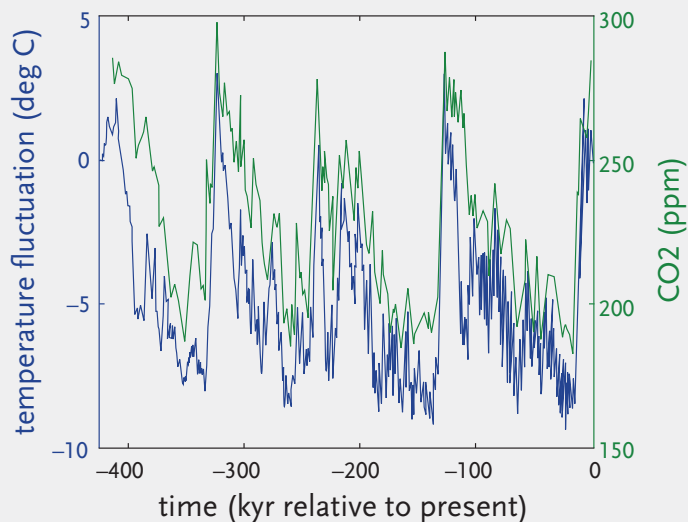
equally important, reconciling it with observations. We stress that our main objective is not to provide more resources for what we already do. Instead we seek an institutional structure that will fundamentally change the culture of climate science. The idea is to restore theory to its proper role: predicting and explaining the outcome of observations and experiments. Indeed we use the term “theory” broadly, so that it includes any set of ideas, concepts, or methods that lead to a greater understanding of observed or observable phenomena. During the genesis of geophysical fluid dynamics in the mid-20th century, the development of predictive theory was a difficult yet relatively straightforward task. The complexity of the climate system requires new approaches.

Although we cannot specify the details of this new science, we are thoroughly confident about how to foster it. First, we need to provide an intellectual home for outstanding scientists in physics, applied mathematics, chemistry, biology, and earth science interested in applying their skills to the climate problem. Second, we need to connect theoreticians with leading observationalists and experimentalists. The crucial third step is to create an institutional culture that accords its highest values to science that quantitatively predicts or explains observations and experiments. These ingredients are in many ways obvious. However, there are currently entire sub-disciplines of climate science, such as biogeochemistry, where observation is strong but predictive theory is not accorded much significance. Yet no one would deny the central role biogeochemistry plays in the climate problem.

The core of the Lorenz Center would be its faculty and post-doctoral fellows, selected not only for their exceptional accomplishments but also for their interest in pursuing fundamental questions in an interdisciplinary, collaborative context. Post-doctoral fellows would be outstanding recent graduates in physics, applied mathematics, biology, chemistry, and earth science. It is our hope that the Lorenz Center’s endowment would support these top scientists,

freeing them from the necessity of seeking funding from traditional sources. We also envision visiting positions for senior scientists. These short-term appointments would be used in large part to bring observationalists and experimentalists to the Lorenz Center, where they would communicate their most recent findings and explore ways in which they could work with resident scientists. In this way the Lorenz Center would strive not only to be the leading center for climate theory, but also to positively influence observational and experimental research.

In addition to an energetic, interdisciplinary core of top scientists, the Lorenz Center would offer fellowships to attract top graduate students. Prospective graduate fellows would have to meet very high standards to qualify for such fellowships, in addition to the already high admissions standards of MIT. The availability of such fellowships would be advertised in many non-traditional venues,



Fluctuations in temperature and atmospheric carbon dioxide concentration in Antarctica for the last 420,000 years, obtained by analysis of the Vostok ice core [J. R. Petit et al., *Nature* (1999)]. The unequivocal covariation of the two records provides a fascinating window into the relation of Earth’s carbon cycle to climate, yet its explanation remains one of the great unsolved problems of earth science.

such as physics and mathematics departments abroad, and the prestige attached to them and the opportunity to work with the finest climate scientists in the world would serve to attract the very best talent.

We have also instituted a scientific workshop series, to communicate ongoing research internally and externally to scientists at MIT, in the greater Boston area, and beyond, and plan to start a monthly seminar series as well. An annual public outreach lecture named after its funder John Carlson showcases fundamental research in climate science to an even broader community. An important second objective of these activities is to increase the visibility of the Lorenz Center in the international scientific community, thereby helping to attract the most talented graduate students, postdocs, and visitors.

MIT's Department of Earth, Atmospheric, and Planetary Sciences (EAPS) serves as the home of the Lorenz Center and has graciously set aside space on the top floor of the Green Building. This initial location is ideal for starting up: it is adjacent to the Program on Atmospheres, Oceans and Climate, within the same building as most of EAPS, and centrally located to facilitate affiliations with students and faculty from allied scientific disciplines. To help us grow and to provide long-term financial support, the Lorenz Center is seeking to raise an endowment from private donors. Private donations are crucial, because the Lorenz Center's emphasis on innovative, high-risk, fundamental research makes it difficult to procure conventional government funding. Moreover, in fields like biogeochemistry and studies of ancient climate, funding is directed almost exclusively to measurements, observations, and the construction of past environmental records. Such work is immensely important, but it requires the parallel development of theoretical understanding for the acquired data to become useful information.

The Lorenz Center nicely complements ongoing and proposed climate-related organizations at MIT. Not only are its activities closely tied to existing academic programs

in climate science and earth science more generally, but its work also complements and informs activities of the Climate Modeling Initiative, the Center for Global Change Science, and the Joint Program on the Science and Policy of Global Change, thus helping carry new climate concepts into the broader community concerned about global change. Together these programs form a climate hub and fulfill several of the objectives for environmental research proposed by MIT's Initiative for the Environment.

We stress that the Lorenz Center focuses on the enormous intellectual challenge of understanding the physics, biology, and chemistry of the climate system. Perhaps ironically, our center, devoted to curiosity-driven research, may stand the best chance of solving what may be the greatest practical challenge of our generation.



The view from the 18th floor of Building 54: The home of the Lorenz Center.

Frequently Asked Questions

Does the Lorenz Center's research aspire to provide support for or comment on specific climate policy agendas?

The founders of the Lorenz Center understand that all sides of the climate policy debate have historically used and will likely continue to use climate science to support or criticize specific policy agendas. The center is devoted to fundamental scientific research and assiduously steers clear of policy debates in its work, and indeed actively disassociates itself from all efforts to characterize the center's work as supporting climate policy positions of any kind.

What is the relationship between the Lorenz Center and MIT's Department of Earth, Atmospheric, and Planetary Sciences (EAPS)?

EAPS is providing the home for the Lorenz Center.

How will the Lorenz Center fund itself?

We are seeking an endowment to fund postdoctoral and student fellowships, visiting scientists, and supporting programs.

What happens if private donors have a political agenda?

The Lorenz Center will be devoted to fundamental science, and will accept from any source that wishes to support that mission.

How large will the Lorenz Center be?

Within the next several years we'd like to support about a half-dozen postdocs, and soon after a similar number of graduate students. Added to this we expect a steady flux of visiting scientists. We may then grow, but the group will always be small enough so that collegial interaction will occur on a daily basis.

Could the Lorenz Center become a "virtual center," spread throughout MIT?

No. Our intention is to foster fundamental discovery by bringing a diverse group of scientists into close daily contact with one another.

Since MIT is already a leader in fundamental climate science, why did you create the Lorenz Center?

Because we can do better, by making the field more attractive to outstanding young scientists with a wide range of disciplinary skills.

If this is the best way to make progress in climate science why haven't you been doing this already?

In fact we have, but at a much smaller scale than necessary to make significant headway on the problem. Emphasis on funding in climate science is on the development of large models, which while important do not always lead to advances in fundamental understanding. We seek to make our field attractive to deep, original thinkers.

What outcomes can we expect from the Lorenz Center?

Our essential "deliverable" is the scientific knowledge arising from fundamental discovery. A second but no less important outcome will be a change in the culture of climate science. As our success becomes known, we expect that our emphasis on fundamentals will not only produce a new cadre of young scientists focused on basic climate science, but also a demand for their skills at universities and government labs throughout the world.

Naming Opportunities

We seek partners in the establishment of the Lorenz Center at MIT. We need support for postdoctoral researchers, distinguished visitors, graduate students, and the center's activities.

Please join us in this new venture by considering the naming opportunities listed below. Of course, gifts in any amount for unrestricted use of the Lorenz Center are appreciated.

*	Name the Postdoctoral Fellowship Program: \$1,200,000 Support three postdoctoral fellows for 5 years
*	Name the Distinguished Visitors Program: \$1,000,000 Provide support for two visiting scientists for 5 years
*	Name the Graduate Student Fellowship Program: \$1,200,000 Provide support for three graduate students for 5 years
*	Name one postdoctoral fellow each year for 5 years \$400,000
*	Provide administrative support for 5 years \$325,000
*	Name one postdoctoral fellow for 1 year \$80,000
*	Name one graduate fellow for 1 year \$80,000

Please contact Ms. Elizabeth Chadis, Assistant Dean for Development, for more information about the Lorenz Center. To give online, visit giving.mit.edu/EAPS and click on the Lorenz Center fund.

With your support, the Lorenz Center has the capacity to become the world's preeminent organization for the study of the climate system.

“The position of MIT is that we must rely on scientific inquiry to determine whether climate is being affected by human activity. While the majority of MIT climate scientists, like the majority around the world, believe that the data and analysis have already established this conclusion, they also believe more research needs to be done. The establishment of this center is supported by all of our climate scientists, including those who are skeptical about the effects of human activity. I urge you to contribute to the formation of the Lorenz Center.”

— Marc Kastner, Former Dean of the MIT School of Science.

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