

Climate Change: A Call to Action

There is no longer doubt that climate change is happening and that human activity is a primary cause. The need to take action is real.

For nearly six decades, Columbia University has played a leading role in understanding our planet's climate system. We stand now at the cutting edge of research to understand how human activity is affecting the planet's physical systems and how we can act to reduce emissions of carbon dioxide, the main driver of human-induced climate change, before it is too late. The more we can understand our changing world, the more we can hope to design solutions for protecting the planet and humankind, particularly the most vulnerable.

In addition to performing groundbreaking research, the Earth Institute at Columbia University is committed to finding and communicating solutions to climate change and its effects. We are training a new generation of scientists and professionals who can make a difference in the world.

WARMING CLIMATE, VANISHING ICE



The geological canaries of climate change, glaciers and polar ice are showing distinct signs of decline. As global temperatures warm, the earth's ice is beginning to melt—in some places, far faster than models predicted just a few years ago—and sea levels are rising. The world has seen ice retreats and dramatic turns in climate before, but never as the result of human activity.

To better understand what is happening, our scientists are hunting for clues in the “climate archives” of the past and studying the behavior of modern-day ice sheets.

Ice Age Mysteries with Modern-Day Relevance

“Ongoing climate change doesn’t tell us much by itself,” says Joerg Schaefer, a geochemist at the **Lamont-Doherty Earth Observatory**. “But putting it in the context of historical change allows us to evaluate the changes properly.” Reading the climate clues of the past helps us better understand present change and create more accurate models of future climate scenarios.

On the surfaces of rocks in Manhattan’s Central Park, Schaefer and his team found clues to an Ice Age mystery—the retreat of the Laurentide ice sheet, which at its fullest extent about 20,000 years ago stretched from Greenland over Canada all the way south to New York City. Armed with a new tool called cosmogenic dating, the team was able to time the glacier’s retreat with greater precision than would have previously been possible.

What has driven ice ages? How significant is the glacial retreat today? The collapse of land ice has dramatic implications for supplies of global drinking water and sea level rise and may speed up abruptly in response to slight climate shifts. Schaefer and others, including postdoctoral researcher Mike Kaplan, students and laboratory technicians, are addressing these questions through glacial studies on several continents.

Opposite page: Researcher Robin Bell filming a moulin, a hole through which surface water enters a glacier (top). Climate expert James Hansen speaking to a congressional global warming committee (bottom).



Restless Ice

Bound within the land-based ice sheets of Greenland and West Antarctica is enough water to raise global sea levels by 14 meters. There are worrisome indicators that some of this ice is becoming unstable.

Lamont-Doherty seismologists Goran Ekstrom and Meredith Nettles have observed a significant increase in the rate of earthquakes along the coast of Greenland. As ice moves toward the sea, it lurches powerfully enough to trigger measurable tremors. These earthquakes have more than doubled in frequency in the last decade, which suggests Greenland’s ice is moving much faster than it used to.

In Antarctica, scientists Robin Bell and Michael Studinger have discovered rivers of ice and large freshwater lakes of free-flowing water beneath the ice sheet. These have implications for ice sheet stability, as liquid water can lubricate the movement of ice and accelerate the passage of ice sheets toward the sea.

Doug Martinson has observed the decay of ice along the western coast of Antarctica through his studies of the powerful Antarctic circumpolar current, which sweeps past the continent “like a freight train of hot coals.” He found the water it delivers has been warming for over a decade, applying a tremendous degree of melting heat to the outer edge of the West Antarctic ice sheet.

Sea Level Rise

Ten percent of the world’s population lives within 10 meters of sea level, indicates spatial analysis work done by the **Center for International Earth Science Information Network** (CIESIN) and others. As sea level rises, significant portions of major cities like New York and Kolkata, India, and entire regions of countries such as the Netherlands and Bangladesh could be at risk for flooding and storm surges. The world’s poor will be especially vulnerable.

To help officials tackle the expensive challenge of protecting New York City from the effects of climate change, the **Center for Climate Systems Research** (CCSR) and the **NASA Goddard Institute for Space Studies** (GISS) have generated specific climate projections for the area. Without careful planning and action, predicted higher temperatures, sea level rise, enhanced storm surges and changing precipitation patterns in the coming decades could have significant effects on the city’s ability to provide drinking water and manage storm water and waste water.

Approaching the Tipping Point

For James Hansen, director of the NASA Goddard Institute for Space Studies and an adjunct professor at Columbia, performing great research is not enough. Communicating the science and threat of climate change is a moral imperative.

Since his assertion in the journal *Science* in 1981 that global warming caused by increasing levels of carbon dioxide would happen much faster than predicted and his subsequent testimony before the U.S. Senate in 1988, Hansen has worked to bridge the gap between science and public policy.

Hansen has been making the case that scientists’ habitual reticence, though sometimes appropriate, can also hinder their ability to communicate necessary information to policy-makers. For example, the predictions of global temperature and sea level rise made by the United Nations Intergovernmental Panel on Climate Change (IPCC) were conservative, and necessarily so, says Hansen.

However, they did not include the very real possibility that feedbacks such as the sudden melting of ice sheets and the increasing release of greenhouse gases from terrestrial and marine areas due to global warming could accelerate the steadier rate of warming and melting of ice the panel predicted.

“The earth is dangerously near a tipping point at which human-made greenhouse gases reach a level where major climate changes can proceed mostly under their own momentum.”

► Support from the Rockefeller Family Fund, the Flora Family Fund, the Charles Evans Hughes Memorial Foundation and Gerry Lenfest has been instrumental in allowing James Hansen to communicate to the public and decision makers through presentations, testimonies and papers at times when he must dissociate himself from his government position at the NASA Goddard Institute for Space Studies.



DYNAMIC OCEANS



Oceans cover nearly three-quarters of the earth and play a vital role in shaping climate. They absorb carbon dioxide from the atmosphere and affect the weather patterns we feel on land. Although there is still more to learn about the way oceans behave, it is clear they are responding to anthropogenic climate change. Our scientists are helping unlock the secrets of our world's great waters.

Ocean Currents: Feeling the Effects of Human Activity

In the 1990s, Peter Schlosser, associate director and director of research at the Earth Institute, and his colleagues at the Lamont-Doherty Earth Observatory discovered an abrupt change in the Greenland Sea. The formation of bottomwater—dense, cold water that sinks rapidly from the surface to the bottom—had suddenly slowed.

It is possible that an increase in fresh water in the Greenland Sea from melting ice and other sources triggered the abrupt slowdown. Oceans are complex, and the group continues to track changes in the Arctic Ocean, which exchanges water with the Greenland Sea. “The feedbacks associated with rising temperatures and melting ice, such as the unexpected drop of the sea ice extent in the Arctic Ocean in 2007, could affect global circulation patterns,” says Schlosser, “and need to be monitored.”

In the North Atlantic, Bill Smethie is tracking the formation of part of the headwaters of the great conveyor belt, a global circulation pattern that is critical to the stability of the world's climate.

Off the coast of Antarctica, Arnold Gordon and colleagues are observing how frigid water plunges to great depths from the continental shelf and flows north to the equator and beyond. With global warming, this bottomwater and the dense water formed in the North Atlantic could slow down or stop being produced, which would impact ocean temperatures.

“Poking the Angry Climate Beast”

Since Wallace Broecker first began studying the world's oceans in the 1950s, he has made tremendous contributions to the study of our changing climate and influenced a generation of scientists.

Broecker's new book, *Fixing Climate*, which he wrote with science writer Robert Kunzig, tells the story of our evolving understanding of human-induced climate change, a story whose emergence and milestones are mirrored by Broecker's own career.

In 1975, Broecker warned that the short period of cooling the world was experiencing would soon come to an end and increasing levels of carbon dioxide could lead to a pronounced global warming. A few years later, he went on to propose his now-famous idea of a “great conveyor belt” in the oceans, the powerful system of marine currents that distributes heat around the world and helps regulate Earth's climate.

Through studies of the climate record, Broecker observed that abrupt climate change has happened in the past and could happen again as a result of global warming. There are risks to “poking the angry climate beast with CO₂,” says Broecker. “We're pouring CO₂ into a system that we don't really understand, and therefore prudence says that we have to be prepared to cut the flow.”

Fixing Climate, like Broecker himself, does not focus on oceans alone, but covers many parts of climate science and emphasizes the importance of reducing carbon emissions. “If we are to avoid dangerously warming the planet, we need to figure out how to build the equivalent of a sewage system for carbon dioxide,” write Broecker and Kunzig. Keeping our CO₂ emissions from further “polluting” the atmosphere will not be cheap or easy, but energy research is finding possibilities—and this gives Broecker hope.

► Funding for *Fixing Climate* and for some of Wallace Broecker's recent work, as well as the lead gift toward the construction of a new geochemistry building on the Lamont-Doherty campus, was provided by the Comer Science and Education Foundation and the late Gary Comer. Comer first contacted Broecker after he witnessed the melting of Arctic ice while navigating his yacht through the Northwest Passage above Canada.

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Photo: Torbjörn Andersson

Inhaling and Exhaling Carbon

Of all the carbon dioxide that humans emit into the atmosphere, about a quarter is absorbed by the oceans. If they continue to warm, their storage capacity could decrease.

“Think of a beer that's warm,” says Lamont-Doherty researcher Taro Takahashi. “It fizzes quickly and loses its carbonation quickly, while a cold drink will stay bubbly longer.”

For the better part of four decades, Takahashi has been mapping carbon dioxide concentrations in the global oceans to find out where they absorb carbon dioxide and where they release it. The picture is complex. Takahashi has collected several million data points since 1960 and is seeing that some ocean regions, like the northwestern Pacific, are absorbing more carbon dioxide than before, while others, such as those near Antarctica and around Iceland, are absorbing less.

Other scientists at Lamont have pioneered the direct measurement of the movement of carbon dioxide between the ocean and the atmosphere. On an expedition led by Lamont-Doherty scientist David Ho, a number of researchers braved the high winds and big waves of the Southern Ocean to learn more about the relationship between oceans and the large amount of carbon dioxide that remains in the atmosphere.



Photo: Alisa Frohman

Above: Yasemin Erboy, Columbia College class of 2009, studying atmospheric concentrations of a man-made gas with research scientist Bill Smethie. Each year a group of undergraduates from Columbia College and Barnard College spend their summers at the Lamont-Doherty Earth Observatory as Earth Interns, researching topics related to climate change, oceanography and many other aspects of life on Earth.

WHERE SCIENCE AND SOCIETY MEET



Pushing the boundaries of climate science is only part of the approach to tackling the challenge of climate change. At the Earth Institute, we are working to communicate what we know, understand how people make decisions in the face of environmental uncertainty, and facilitate action-oriented dialogue among multiple stakeholders.

Decision Making Under Climate Uncertainty

How convinced are you that global warming is happening? If global warming is happening, do you think it is caused mostly by human activities? These and other questions were posed by the Earth Institute's **Center for Research on Environmental Decisions** (CRED) in a recent survey of 1,000 New York City residents.

CRED seeks the answers to questions like these to get at the heart of how individuals and groups make decisions under climate uncertainty and how that decision making happens in the face of environmental risk. Their research has suggested that firsthand experience of both gradual climate warming and extreme weather events associated with climate change plays a greater role in the public's response. This suggests policy-makers need to make the threat of climate change more personal and immediate in order to inspire action.

The message is getting through to New Yorkers. The majority of those surveyed felt humans were responsible for climate change and needed to do something about it. "Recent vivid and memorable media coverage of climate change impacts in Alaska, Florida, the American Southwest and other locations close to home have brought global warming onto the radar screen of the residents of New York, elevating it to a risk worth worrying about," says Elke Weber, director of CRED.

Forging Consensus on Climate Change

Through the **Global Roundtable on Climate Change** (GROCC), we are forging international consensus on climate change among high-level stakeholders from the private sector, international governments and nongovernmental organizations.

Early in 2007, the Roundtable released "The Path to Climate Sustainability: A Joint Statement by the Global Roundtable on Climate Change," which highlights the importance of increased energy efficiency and the need to use alternative energy sources and deploy technologies to capture and store carbon dioxide. The statement was endorsed by 108 companies from around the world and by 138 individual leaders from business, civil society, government and research institutions; and it was introduced at the United Nations Climate Change Conference in Bali, Indonesia, at the end of 2007.

GROCC's several hundred participants have regularly convened at the Earth Institute. Working groups are conducting projects such as reducing emissions from deforestation in developing countries, solar-powered LED lighting solutions and the sequestration of carbon in basalt deposits.

The new **Columbia Climate Center** will coordinate climate science work at the University, propose climate change mitigation and adaptation strategies, and improve communication between scientists and decision makers. Read more in the Climate Center profile on page 28.

Training a New Generation of Climate Leaders

There is a great need in the world for professionals who understand the link between climate and society and can lead the way toward mitigating and adapting to the effects of climate change. The **Master of Arts Program in Climate and Society** gives students the knowledge and skills to meet this acute need.

Arame Tall

Throughout her time at Columbia, Arame Tall was committed to returning home to Senegal and making a difference. She could see the change in herself as a result of the Master of Arts Program in Climate and Society. "A year ago I was as clueless about climate issues as the average person you would meet on the street," she says.

Just weeks after graduation, Arame was back in Senegal, giving a presentation on the use of climate risk management tools to a group of disaster managers at the Red Cross Federation. "They left with a better understanding of how they can use the tools developed at IRI [International Research Institute for Climate and Society] and other academic centers to improve the quality of their interventions on the ground and save more lives," says Arame.

"Now they turn to me for guidance, expertise and advice," she says. "This is evidence of the tremendous amount of learning that I have undergone over the course of the past year at Columbia, one which has opened many doors for me."

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Above left: Arame Tall was the 2007-2008 recipient of the Pulitzer Fellowship, funded by the Pulitzer Foundation. *Above right:* Kalpana Venkatasubramanian attended Columbia with scholarships funded by the MSST Family Foundation.

Kalpana Venkatasubramanian

While working as a research associate in India, Kalpana Venkatasubramanian began to read about climate change and realize its far-reaching impacts. "In India, it had yet to be taken up as a big issue, especially on the policy front. But I knew it was going to affect many aspects of our lives."

She saw the Master of Arts Program in Climate and Society as a way to supplement her experience in the social sciences with a scientific understanding of the way Earth's climate works. Like many of her classmates, some from scientific backgrounds and others from social science backgrounds, she felt she understood only part of the picture. "I felt if I learned more about the science part of climate issues and how climate impacts social life, I could integrate this into research, policy and action."

Kalpana saw the importance of outreach when she visited a school in Harlem. She and her classmates talked about climate change to a receptive group of kids. "The biggest challenge we face is getting the right information out to people," she says. "Communicating the climate change issue in such a way that people comprehend the direct as well as indirect impacts on their very lives and livelihoods is extremely important."

Kalpana plans to return to India, but she will maintain the connections she has made through her international classmates. "Climate change is a challenge that transcends borders," she says. "Facilitating the transfer of relevant knowledge, technology and resources across countries is crucial in the efforts to mitigate it."

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MEETING THE WORLD'S ENERGY NEEDS, REDUCING CARBON EMISSIONS



Photo: Sigfus Mar Pálsson

When it comes to tackling the challenge of reducing carbon dioxide emissions, Earth Institute scientists and engineers think big. From exploring ways to capture and store carbon, to addressing issues of energy policy, we are pursuing strategies to meet the world's significant energy needs while keeping climate change at bay.

Why Carbon Capture and Sequestration?

"The world right now is running on roughly 85 percent fossil fuels," says Klaus Lackner, Ewing-Worzel Professor of Geophysics and director of the **Lenfest Center for Sustainable Energy**. "And consumption of these fuels invariably means CO₂ emissions." Atmospheric concentrations of CO₂, the main driver of climate change, may become dangerous at levels much lower than commonly believed. "If this is the case," says Lackner, "we are already in trouble."

This is where carbon capture and sequestration technologies come in. Given the need to continue using energy that generates carbon dioxide—coal, for instance—we need to find a cleaner way to produce it. Technologies to store and sequester carbon are not cheap and skeptics worry that they will just "create one problem by trying to solve another," says Lackner. "This reinforces the need for research; we need to not only come up with new technologies, but to understand what their impacts will be before we deploy them."

Storing Carbon Dioxide Beneath the Ocean Floor

Carbon dioxide is denser than water in the cold, high-pressure depths of the ocean, a key phenomenon behind research into the injection of excess carbon into suboceanic rock formations. Once injected, the carbon dioxide will be held in place by gravity. Several Lenfest Center researchers have established that there is great theoretical potential for extensive and long-term storage of carbon dioxide under the ocean. Their research is now focused on determining the long-term fate of carbon stored in this way and developing practical ways to apply this technology.

Above and opposite page: Research at a geothermal energy plant in Iceland is finding out more about the trapping of carbon dioxide emissions in basalt, a rock type found in many parts of the world.

Capturing Carbon Dioxide in Basalt

Many energy researchers are exploring ways to pack loose carbon dioxide into storage places in the ground as a way to dispose of it. Jürg Matter, a researcher affiliated with the Lamont-Doherty Earth Observatory, is looking for a more stable storage method.

At a geothermal energy plant in Iceland, Matter is studying how fast carbon dioxide will react with basalt—a rock type that reacts naturally with the gas and is found in many parts of the world—when it is injected into the ground. By 2009, he hopes the plant will be ready to start trapping a portion of its carbon dioxide emissions in the basalt near the plant.

Designing Advanced Zero Emission Power Plants

Graduate students supported by the Lenfest Center are focusing their efforts on the development of a technology roadmap for power plants that integrates sophisticated techniques to keep carbon dioxide out of the atmosphere. As part of this project, Xinxin Li, a Ph.D. student in earth and environmental engineering, interned with the Chinese Academy of Social Sciences during the summer of 2007 with the support of the MSST Foundation and researched the state of clean coal technology in China.

Atmospheric concentrations of CO₂, the main driver of climate change, may become dangerous at levels much lower than commonly believed. This is where carbon capture and sequestration technologies come in.



Photo: Jürg Matter

The Pursuit of Influential Energy Solutions

"It's only the second year of the Lenfest Center, but we have some brilliant minds here, and I believe we will be a leader in the field of sustainable energy."

When rising star Ah-Hyung Alissa Park was invited to come to Columbia University to give a seminar on her work in sustainable energy and the mineral sequestration of carbon dioxide, she knew she was being interviewed, but she did not know about the offer she would soon receive to be the Lenfest Junior Professor in Applied Climate Science.

She debated about taking a job outside of a chemical engineering department and about moving to the big city, but the last year has shown that Park, the Lenfest Center for Sustainable Energy where she is now associate director, and New York are a good match. "Being in New York City, particularly at Columbia University, makes my vision much bigger. It helps me see how my work impacts people and how we can influence advancements in science and technology as well as environmental decision making."

Park's current research is on the clean synthesis of hydrogen and liquid fuels from carbon-containing substances like coal and biomass—solid municipal waste or industrial waste, for instance—in a way that reduces the release of carbon dioxide into the atmosphere. "It's only the second year of the Lenfest Center," says Park, "but we have some brilliant minds here, and I believe we will be a leader in the field of sustainable energy and specifically carbon capture and storage."

When Park first told her parents about her decision to pursue advanced studies in chemical engineering instead of medicine, they encouraged her to reconsider. "I really want you to do something that's good for people," Park's mother told her. She saw medicine as the best way to do that.

Now, years later, Park's mother has changed her mind about her daughter's profession. She has seen news stories about global warming and has realized the importance of what Park and her colleagues at the Lenfest Center do. Their work is not just about academic pursuits; it is about improving people's lives.

► Funding for the endowed professorship that Alissa Park holds and the Lenfest Center for Sustainable Energy was provided by Gerry Lenfest and the Lenfest Foundation.



Photo: Bruce Gilbert