[SLICE OF MIT THEME MUSIC]

ANNOUNCER: You're listening to All Ears MIT, a production of the MIT Alumni Association.

HOST: What's the science behind climate change? And how can we combat this threat to the earth? These are complex questions, but questions tailored to the Mens et Manus, mind in hand, mindset of MIT.

MIT's conversation on climate change initiative and many faculty members are working on understanding the issues and finding ways to offset atmospheric changes caused by human activities. In this All Ears MIT episode, we'll hear from four MIT faculty members whose research focuses on climate change.

These interviews were culled from the alumni associations faculty forum online series, monthly live webcasts that feature faculty interviews on timely and relevant topics. Watch the entire webcast series on Alum.MIT.edu.

Public debates on climate change tend to be centered around complex numerical models-- great for predicting quantitative estimates on the climate's future, but at times, a roadblock to collaborative discussions and solutions.

Professor Kerry Emanuel, who earned his degree in earth, atmosphere and planetary science in 1976, and his PhD in meteorology in 1978, is a professor of astronomy in MIT's Department of Earth, Atmospheric and Planetary Sciences, and takes an approach that emphasizes basic understanding over simulation.

Emanuel is best known for his research on hurricane activity, which earned him a spot on *Time Magazine's* list of the world's 100 most influential people in 2006.

He's also the author of *What We Know About Climate Change,* a book *The New York Times* called, the single best thing written about climate change for a general audience. He points out that climate change and the discussions around it are far from new issues.

KERRY EMANUEL: Climate science is not a new science. By the middle of the 19th century, some of the great mathematicians and scientists of that era understood very well that the surface temperature of the Earth was much warmer than it would have been otherwise, thanks to the presence of gases that exist in trace quantities in our atmosphere-- gases like carbon dioxide, methane,

and nitrous oxide.

Now, one fact that we have understood for 100 years is that if we took away the greenhouse gases, the Earth's mean surface temperature would plummet from 60 degrees Fahrenheit to zero degrees Fahrenheit. If you just took away carbon dioxide, all by itself, you go from 60 degrees to 42 degrees.

So it stands to reason that if you double carbon dioxide, you're going to see a big change in temperature. None of this is controversial, or has been controversial until recently, in science. But that's the way it goes. Now, why should we be concerned about this?

There are some reasons that warming the planet would be a good thing. Climate does change naturally. It changes for a variety of reasons, including changes to the Earth's orbital parameters, tilt of its axis, and so forth, the elasticity of its orbit about the sun.

So if we turn the clock back 22,000 years, when the orbital characteristics of the Earth were a little bit different, which change the distribution of sunlight, the Earth's surface temperature was at about eight degrees or nine degrees Fahrenheit lower than today. And the sea level was 400 feet lower than today.

We're projecting-- science is projecting that the temperature will go up by seven or eight degrees Fahrenheit by the end of the century. And the last time the planet was that warm was when the sea level was about 100 feet higher than today's.

Now, climate science is predicting, on the other hand, that sea level, by the end of the century, should go up by three or four feet. That's a very conservative estimate. If it did go up 100 feet, you'd lose a lot of the major cities in the world.

HOST: Emanuel also discussed the correlation between carbon dioxide in the atmosphere and global warming. Carbon dioxide plays a crucial role in regulating Earth's surface temperature. It currently constitutes about 0.04%, or 400 parts per million, of the Earth's atmosphere. That's the highest percentage in the past 800,000 years-- a level that Emanuel says could take centuries to reduce.

EMANUEL: Carbon dioxide is the most important influence that we're having, but we're also putting methane, nitrous oxide, chlorofluorocarbons. But carbon dioxide's special. It's a special cause for worry because it's lifetime in the atmosphere is very long. It takes, literally, thousands of

years to get rid of it.

So whenever-- if we were to stop putting carbon dioxide in the atmosphere today, the level that we've already ramped it up to-- you know, we started at 280 parts per million before the Industrial Revolution. We're up to about 400 today.

Even if we stopped, went cold turkey today, that 400 will be around for many, many, many generations. And the temperature effects that go along with it are around for many generations. So that's why we don't, unfortunately, have the luxury of waiting.

HOST: Emanuel's research on hurricane activity placed him among a group of MIT voices who were able to provide context on recent super storms, like Hurricane Sandy in 2012 and Hurricane Katrina in 2005. Those voices also include professor Andrew J. Whittle, who earned his Doctor of Science in civil engineering at MIT in 1987.

Whittle served on a panel reviewing the hurricane protection systems in New Orleans following Hurricane Katrina. The hurricane flooded and decimated huge areas of the southeastern US and the Florida and Gulf Coasts, and raised awareness about the fast growing threat of severe coastal flooding.

ANDREW WHITTLE: In Katrina, we saw probably the largest surge in the US, which was, in some places, as much as 30 feet, or 10 meters. And in the case of Sandy, of course, it was something in the order of 14, 15 feet around battery point-- down in Battery Park, down in the tip of Manhattan.

HOST: According to Whittle, there are many factors behind increased coastal flooding, including superstorm events, such as hurricanes, that can produce massive storm surges, as well as the long-term rise in sea level, which is associated with climate change and a warming global climate.

WHITTLE: Sea level is rising. And we know that's occurring at a much slower rate, but we might expect another three foot of sea level rise by the end of this century. So that will, of course, add to the effect of the storm surge. And then, I think, most critically, as the temperature of the sea increases in the tropical areas, the potential for more intense storms has appeared.

You combine those together and we really are facing a situation where big coastal flooding events are likely to be more frequent over the next century. The tropical storm systems coming from the Atlantic, which affect all of the Gulf of Mexico and the east coast of the US-- they're the ones we're primarily concerned with.

So Sandy is a good example-- Katrina in New Orleans a few years ago. I think what has been spectacular in both those two particular storms was the very large storm surge that they generated. And the storm surge is essentially the rise in mean sea level that's occurring.

HOST: While factors like carbon dioxide and sea level are common issues associated with climate change, less is known about the correlation between clouds and climate change-- an issue that Dan Cziczo, an associate professor of atmospheric chemistry in the Department of Earth, Atmospheric and Planetary Sciences, is finding out.

According to Cziczo, while we know that clouds can help offset warming from greenhouse gases and help cool the Earth, we're still learning what effect so-called human-made clouds-- the manufactured particles in the atmosphere that interact with water vapor and temperature to form clouds-- will have in a shifting climate that continues to get warmer.

DAN CZICZO: So what we're focused on is understanding particulate matter. And particulate matter is-- it's much less well-understood when it comes to climate change. So just as human activities are adding greenhouse gases to the Earth's system, they're also adding particles.

And those particles can do two things. One thing is that they can scatter some radiation back into space. So this is the solar energy of the sun's rays, which are coming into the planet. And some fraction of those are scattered back into space by particles.

Particles can also form clouds. And, as anybody flying around in an aircraft knows, when you fly over the top, these are very white, so they're very reflective. It's like walking out on a partly cloudy day. When you're under the cloud, the temperature is a lot lower. You don't feel the sun's energy hitting you. And this is the same for the whole earth system.

So, although we know greenhouse gas emissions and their effect rather well, human activities are also putting out particles, we're also changing clouds, but we don't understand those effects quite as well.

HOST: Of course, any discussion of climate change would be incomplete without the inclusion of politics. Specifically, the policies that would need to be enacted, for example, to lower carbon emissions and reduce greenhouse gases.

And history has shown that climate change policy can be complex, expensive to implement, and have unintended consequences on the environment.

Professor Christopher Knittel, a co-director of MIT'S Center for Energy and Environmental Policy Research, is working to create climate policy that is more efficient and economically sustainable. Knittel is a research associate at the National Bureau of Economic Research, and an associate editor of the *American Economic Journal.*

CHRISTOPHER KNITTEL: I like to say the US was built on cheap gas. We have suburban sprawl. Our population density is much less dense than Europe. So we've become accustomed to relying on the automobile.

That implies that any change in our policies is going to be very difficult at the beginning because these behavioral-- long-run behavioral changes take a number of years to implement, whether it's changing the vehicles that we drive, our land use patterns, and so forth.

HOST: Knittel argues that if we want to reduce emissions from the transportation sector, we need incentives for people to drive less or purchase more energy efficient vehicles. And the most cost effective way to do this is through a carbon tax, or a cap and trade system-- a behavioral change that may be difficult to implement.

KNITTEL: The biggest incentive is to actually raise the price of gas. The sorts of behavioral changes that consumers implemented during the 2008 run up in gas prices-- you see a tremendous amount of behavioral change coming all the way from changing what cars they buy to how many miles they drive.

I've done some work that even documents within a household, we see households shifting from the fuel inefficient car to the fuel efficient car.

HOST: Knittel also mentions subsidies for public transportation, an often overlooked option that has tremendous potential for impacting consumer behavior and increasing the prevalence and efficiency of transportation systems. Although often controversial, economic policy and regulation could play a large role in reducing atmospheric emissions.

So where do we go from here? A unified rational commitment from established and developing countries that lowers carbon emissions, that makes economic sense, would be the best way to start, says Cziczo.

CZICZO: You know, I think that most of the viewers are probably aware of the Kyoto Protocol, which is going to be ending, here, in the space of a few years, which was signed on by many nations

but unfortunately not by the United States. And it also had exemptions for the developing nations.

The two that are most often pointed out are China and India, which have become two of the top five carbon dioxide greenhouse gas emitters. It would be very nice to not only get everybody to buy in, but also have some way of addressing the concerns of developing nations, which, of course, want to develop.

They want to have the standard of living of the developed nations, but also sort of phase in reductions in greenhouse gas emissions. I am certainly not a policymaker, but I think those are the two things.

You have to have buy in by the developed countries-- all of them, not just some of them. And you also have to find a way of sort of phasing in the response by the developing countries, as well.

HOST: Thank you for listening to this All Ears MIT episode on climate change research at MIT. To learn more about the Faculty Forum Online Series, visit the Learn section of alum.mit.edu. For more on MIT's conversations on climate change initiative, visit climatechange.mit.edu. And check out our entire library of MIT alumni podcasts at soundcloud.com/mitalumni.

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