Carbon Curves

https://www.climateone.org/audio/carbon-curves
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Greg Dalton: I'm Greg Dalton. And today on Climate One, we're discussing how human activity is altering our skies and our oceans. The basic physics of the greenhouse gas effect has been studied for nearly 200 years and well understood since the mid 20th century. In the past two decades it has become increasingly clear that burning fossil fuels is disrupting the earth's life support system. Scientists say that in our lifetime, we can expect more severe weather, stronger storms, higher season temperatures, more searing droughts and more extreme floods. Our roller coaster ride is just beginning.

Over the next hour, we will talk about the state of scientific knowledge about climate disruption. We also will talk about stories of hope and the opportunity of clean energy. Joining our live audience at the Commonwealth Club in San Francisco, we're pleased to have with us two of the country's top scientists. Jane Lubchenco served under President Obama for four years as administrator of the National Oceanic and Atmospheric Administration. She's a recipient of the MacArthur Genius award and currently a professor of Marine Biology at Oregon State University. Ben Santer is a climate scientist at Lawrence Livermore National Laboratory. He's also a winner of the MacArthur genius award and author of several influential studies on human-caused global warming. Please welcome them to Climate One.

[Applause]

Greg Dalton: Welcome both. Thank you for coming.

Jane Lubchenco: Thank you.

Ben Santer: Thank you, Greg.

Greg Dalton: Jane Lubchenco, let's begin with you. I read a story about your first day in Washington, you saw something surprising. Tell us what you saw on the first day in Washington. It wasn't Kevin Spacey. It was another kind of -- what did you see?

Jane Lubchenco: When someone is nominated for position that has to be Senate confirmed, you don't go in to your offices, you don't do anything that will communicate to the Senate, you're taking this confirmation for granted. So I had not been inside the NOAA offices until the actual day I was confirmed and sworn in.

I walked in to my office, meet the people that are there, start looking around. It's a very large, interesting big office, nice location. I opened up the door to the bathroom and there is a big Norway rat on the floor, about this big, big tail and it was wet, and that looked at me and jumped. I kind of jumped. My staff was just freaking out behind me. They were just fit to be tied. And then this rat went across the floor, jumped up on my toilet and dove into the toilet and disappeared. And I thought, "Well now, this is going to be an interesting time in Washington D.C."

[Laughter]

Greg Dalton: And I won't ask you if you saw other rats during your time in Washington but I will ask that your time in Washington did see a lot of extreme and severe weather. Tell us about that

period of time. It was quite historic.

Jane Lubchenco: The four years that I was at NOAA which, of course, has the National Weather Service as part of NOAA as well as keeping all the climate records and so we know with certainty what all the records are for everything. We had the most extreme four years of weather ever in U.S. history as far back as the records go for different categories. We had 770 major tornadoes in those four years. We had 70 Atlantic hurricanes, six major floods, three tsunamis, record-breaking snowfall and blizzards, drought, prolonged heat waves and wildfires. Every different possible category of extreme weather we had in spades.

And another thing that NOAA tracks is the economic consequences of all this extreme weather. And typically, in an average year, there would be on the order of $3 billion to $4 billion worth of damage from extreme events. We track the number of extreme events that cost at least a billion dollars in damage. And normally, there would be three to four of those. I misspoke earlier.

And during 2011, we had a record-breaking 14 at least $1 billion events. And in 2012, we had 11. So in those two years, we had 25 extreme weather events that cost at least a billion dollars in damage. So there was a lot of extreme weather that we had to forecast, make sure people knew how to stay out of harm's way. But I think that that extreme weather actually changed a lot of people's opinions, a lot of people around the country started saying, "What the heck is going on?" because it was just so extreme.

Greg Dalton: Ben Santer, how do we know -- are there human fingerprints on this kind of weather? How do we know if Mother Nature is not just slapping us around a little bit?

Ben Santer: I think the answer is yes, we do know. For many years, people who have been looking at cause and effect relationships primarily were interested in looking at broad brush changes and average climate. But after the European summer heat wave in 2003, the game changed, and scientists asked for the first time really, what can we say about changes in the likelihood of threshold crossing events like warming of nearly two degrees Celsius over much of Southern Europe in the summer of 2003?

And borrowing really from epidemiology, scientists began to look at this concept of fractional attributable risk how human intervention in the climate system changes the likelihoods of those kind of threshold crossing events, and that's now been done not only for the European summer heat wave but also for droughts, for flooding. So increasingly, in the kind of work I do, looking at cause and effect relationships in the climate system, people are moving from those broad brush changes in climate to what's now called event attribution, looking at specific events and trying to assess human contribution to changes in the likelihoods of those events.

Greg Dalton: So that's a significant change. Many scientists have said here that, "Well, we can't connect the dot between climate and Katrina or climate and Sandy." And you're saying that the vanguard of science is saying, "Yes, we can."

Ben Santer: Well, the vanguard of science, I think, is looking at how human activities, how human-caused warming of the oceans, the surface, the atmosphere, moistening of the atmosphere is changing the likelihoods of those kind of threshold crossing events and there is recognition that we can now, as scientists, may confirm statements on how we're changing those likelihoods.

Greg Dalton: So let's take Superstorm Sandy, what is the human contribution, Jane Lubchenco, to Superstorm Sandy?

Jane Lubchenco: I think there are a couple of aspects to that question. Much of the damage from Superstorm Sandy as well as the damage from the recent super-typhoon Haiyan was because of the storm surge, and there is no doubt that the storm surge was worse because of sea level rise, which is attributable directly to climate change. So the impact of the storm was much worse because of climate change creating more sea level rise.

The question you were actually asking about was the size of this Superstorm Sandy was a thousand miles across. It was a huge, huge storm. Is that attributable to climate change? And I think what Ben has suggested is that there is a very active area of science that is the science of attribution and I would defer to Ben to answer specifically about Sandy.

Ben Santer: Yes. I think we know again that we're changing some of the large scale conditions that influence the genesis and the development of typhoons and hurricanes. We know what some of those large scale conditions are. The warmth of the ocean surface and the mixed layer immediately below the surface, the amount of moisture in the atmosphere, the so-called wind shear at different levels in the atmosphere, all of these and other things can have some significant influence on the development of hurricanes and typhoons.

And our best understanding is that at least two of these, ocean surface temperatures and the amount of moisture in the atmosphere, are being changed by human-caused changes and greenhouse gases, and they're being changed in a way that would tend to generate more intense hurricanes and typhoons. There's fairly good modeling evidence and theoretical evidence suggesting that in response to continued human-caused warming and moistening of the atmosphere, we should expect to see some intensification of hurricanes and typhoons. The jury is still out in terms of changes in the frequency of these events.

Greg Dalton: Does -- sorry, yes?

Jane Lubchenco: If I may. I think a lot of people have difficulty wrapping their minds around some of the language that scientists use to describe events like this. And we're honoring Steve Schneider tonight and he was one of the champions of trying to find the right analogies to describe things. And he would talk about loading the dice, for example, but I think there's another analogy that's appropriate here in terms of extreme weather events and that's an analogy with baseball.

When a baseball player starts taking steroids, there's a much greater chance that he's going to be hitting lots of home-runs and some big home-runs. Now, that doesn't mean you can point to any particular home-run and say, "Aha, that home-run is because he is taking steroids." But the pattern of more and larger is attributable to his taking steroids. And I think by analogy, what we are seeing was some kinds of extreme weather is weather on steroids, weather on climate steroids.

Greg Dalton: We know a thing or two about steroids involve players here in San Francisco. But some scientists have been here and said that, "The science is very sound on sea level rise. It's very sound on the surface temperatures." But you start talking about typhoons and storms and then it gets a little dicey. It gets a little -- more wobbly there than it is in other places. Is that true that the science is, I would say, less settled, less clear when it comes to these big storms than it is for temperature and sea level rise? Ben Santer?

Ben Santer: As I mentioned earlier, I think in terms of changes in the frequency of these events, that's true. The jury is still out. We don't have a clear understanding, as of today, of whether we will see more hurricanes and typhoons in response to human-caused changes in atmospheric composition and warming and moistening of the atmosphere or we will see fewer of these events. In terms of the intensity, I think there is some relatively good understanding, again, both theoretically

and from computer models of the climate system and for purely basic physics that we should expect to see some small intensification of hurricanes and typhoons.

Greg Dalton: There's been a -- I'm sorry.

Jane Lubchenco: Heat waves are one of the most damaging natural disasters. And I think there is increasing evidence that the very, very large heat waves that we are seeing, we expect to be seeing more of those and lasting longer. And I think the attribution for those is stronger.

Greg Dalton: We've also seen the winter of 2013 saw some pretty strong cold periods of people across the country. What do you say to someone who says, "It's freezing, global warming, huh?" Ben Santer?

Ben Santer: Well, I tell people, "That's the phenomenon we climate scientists refer to as winter."

[Laughter]

Greg Dalton: Yes.

Ben Santer: There seems to be this incorrect expectation that as human-caused burning of fossil fuels has increased levels of carbon dioxide and other heat-trapping greenhouse gases in the atmosphere that we expect each year to be inexorably warmer than the previous year and we expect winter to go away. That never was our expectation.

We know about the drivers of the large seasonal cycle in earth's temperature. We know that there is this rich year-to-year and decade-to-decade natural variability of the climate system. That's not going to go away. That's the backdrop against which we're trying to identify some slowly evolving human-caused warming signal.

So as the little video said, Signal and the Noise, that's what my job is. That's what the job of many of the people in the audience is today trying to identify some human-caused warming signal embedded in this rich noise of purely natural changes in the climate.

Greg Dalton: And one related phenomenon perhaps is the pause or the slowdown recently in global warming, which people point to and say, "Scientists can't explain it, it might not be happening." Ben Santer?

Ben Santer: Sure. Well, I first encountered the pause or the global warming stop in 1998 narrative when I testified in front of Congress in 2010. One of the witnesses made this claim in his official Congressional testimony, "Global warming stopped in 1998. No warming of the surface or the lower atmosphere since then." And computer models of the climate system, when run with human-caused changes and greenhouse gases, cannot produce such hiatus or pause periods. There was no scientific evidence to support that assertion whatsoever. That is what I like to call science by eminence of position. Trust me. I'm a Bigwig scientist here.

So we and many others in the room and around the world had been looking at this detective story at this complex issue of why? Why has there been relatively muted warming of the surface over the last 15 years. It's a fascinating problem. One of the reasons is this internal variability that I mentioned earlier, things like El Niños, La Niñas. The beginning of the last 15 years was the 1997 El Niños event. On average, El Niños tend to warm the planet.

So if you start near a high point, a very large warming event and you end 15 years later with a number of small La Niñas, which on average tend to cool the planet, you're going to get a little or no

increase over that specific time period. But the key thing here is we don't look at short periods of time in trying to identify human effects on climate. That would be just as silly as looking at the minute by minute record of day trading on the Dow to make inferences about the long-term structural changes in the Dow. You don't do that. In the same way, we beat down that year-to-year noise of natural climate fluctuations by looking at very long changes in climate over decades to centuries. That enables us to more clearly discern what is causing the changes.

Another thing about the hiatus is that we know that there had been a number of small volcanic eruptions in the first 13 years of the 21st century. We didn't know that until 2010. Beautiful Paper by Susan Solomon and colleagues in science looked at Mauna Loa observations and saw, "Wow! The reflection of incoming sunlight at the top of the atmosphere has actually increased because we've had over 17 small volcanic eruptions that have contributed some cooling to the real world over the last 15 years or so." That's part of the answer.

Also the last solar cycle, the solar minimum was unusually low and long relative to the two solar cycles preceding. There's an 11-year solar cycle in the sun's energy output. All of these things have made some contribution to the pause or hiatus in warming. The key point though is that this does not cause us to fundamentally revise our understanding of climate change.

Computer models too, even when run with historical changes in human-caused greenhouse gases produce such pauses as well as many people have showed because of natural climate variability. And again, in the case of the observed hiatus, there seem to be other factors in play to not just internal climate noise but also volcanoes and the sun.

Greg Dalton: Ben Santer is a climate scientist at Lawrence Livermore National Laboratory. Let's talk about oceans. The Arctic often comes up. Jane Lubchenco, why is the Arctic so important in the overall scheme of understanding and predicting climate disruption.

Jane Lubchenco: The Arctic is really important because of the roles that it plays globally and the fact that it is warming twice as fast as the rest of the planet is really, I think, brings attention to its importance. The sea ice in the Arctic has, as everyone knows, been melting at a rate much faster than was predicted and that has a lot of consequences that we are only beginning to understand.

There are some hypotheses, for example, that suggest that changes, both the melting of the Arctic and then the changes in reflectivity because the ice is no longer there and the ocean is absorbing more of the heat's energy, may have consequences, for example, for the path of the jet stream. There are a number of really interesting changes that we're seeing. We know that the Arctic has an influence on the rest of the planet but we're just beginning to tease out all the ways in which that's playing out.

Greg Dalton: And why should we care about the jet stream? What does that do for us? Ben Santer?

Ben Santer: Well, it sort of steers mid-latitude storm so the location and the strength of the jet stream in our latitudes at winter time is an important factor in determining where storms are. We do care about its location and the things that might act to change its average location.

Greg Dalton: So it could change the temperature in Europe, for example, or change seasons?

Jane Lubchenco: Or the temperatures here. I mean the fact that we've had this real spate of cold weather the jet stream is much farther south than it typically is but it does move around. The question is whether that movement is really being impacted by changes in the Arctic.

Greg Dalton: And the left hook, the famous left hook that Sandy took.

Jane Lubchenco: Yes.

Greg Dalton: That surprised people that, "Whoa! That storm is not supposed to go there." Could the jet stream have influenced that?

Jane Lubchenco: So that left-hand turn into New York-New Jersey was predicted by the scientists at NOAA and in Europe who study that but it was very atypical behavior for a hurricane. Normally, they would simply curve away from the coast line and go out to the Atlantic. And the fact that it took the sharp left-hand hook was very unusual and that was because there was a blocking pattern that was a mass of air over Greenland that essentially steered it into the land.

Greg Dalton: Another change is the conveyor belt. What do we know about the conveyor belt and how that's changing and what the implication is, Jane?

Jane Lubchenco: Ben?

Greg Dalton: Ben?

[Laughter]

Jane Lubchenco: These are Ben's area.

Ben Santer: Well, our expectation is that the conveyor belt circulation, this ocean circulation mode that in the Atlantic is responsible for transporting a lot of warm water northward and keeping Northern Europe temperate. Our expectation is that as we continue to warm the atmosphere and as we continue to have more rainfall at high latitudes that this circulation will slow down. That's a fairly robust feature of computer model simulations where you increase greenhouse gases into the 21st century and beyond.

Observationally sadly, we don't have hard data. It would be nice if I could tell you that we had in place some system to reliably monitor, observe changes in the strength of that circulation, particularly in the Atlantic. We don't. We have snapshots say over the last 50, 60 years at individual locations but not a clear observational understanding with what's happening there, which would be urgently needed. That would be terrific if we had that baseline for understanding what's happening to this very important large scale ocean circulation. Our best understanding though is that we're not likely to see some catastrophic collapse in this circulation as was portrayed in The Day After Tomorrow.

Jane Lubchenco: Although, I mean we do know that has happened historically and that it is possible and it's one of these very extreme abrupt changes that people worry about. But I think the majority of folks who have studied this have concluded it's not likely to happen at least in this century. And so, of all the things that are playing out that we do need to be paying attention to, that's probably not one of them.

Greg Dalton: One ocean impact that is getting a lot of attention is acidification. Why is that important? What impact will that have on ecosystems and human food chain?

Jane Lubchenco: Oceans have been actually doing us a major favor by absorbing much -- not much about between a third and -- a quarter and a third of the carbon dioxide that we have put in to the atmosphere the oceans have absorbed, and when oceans absorb carbon dioxide, that there's a change in the chemistry of the ocean and oceans become more acidic.

In the past 250 years, oceans have become almost 30 percent more acidic, which is actually quite considerable and we're only beginning to understand the full ramifications of that change. It is likely to continue to become more and more acidic through time as we continue to pump greenhouse gases, especially carbon dioxide in the atmosphere and the oceans continue to absorb it. We do know from various laboratory experiments that some, but not all species, are very sensitive to changes in pH and the level of acidity.

In particular, those marine plants and animals that have a shell or a skeleton that is made of calcium carbonite and carbonate. And the calcium carbonate or chalk is more difficult -- the shell is more difficult to make when conditions are more acidic and it erodes more rapidly. And so things like oysters, mussels, clams but also corals, sea stars like my sea star or crabs, lobsters, many, many different groups of animals in the ocean but also some very important plants that have shells or skeletons.

If you take these creatures and put them in a laboratory situation that mimics the level of acidity that we expect to happen by mid-century or end of century, many of them show some very significant impacts. The sobering news is that we are already seeing impacts in nature as well, not just in simulated situations in laboratory tanks.

If you go to the Antarctic, for example, there is a very small marine snail called the sea butterfly that's about the size of a lentil bean, and these small animals make shells. They float in the ocean and the shells are already becoming more -- the shells are weakened and they're sort of eroded. That species, not that species, but those sea butterflies, in general, occur in many places in the ocean, and they're very, very important food sources for salmon, for example, and for mackerel. And so not only are they being affected but there is certainly at least the possibility of some knock-on consequences.

Off the coast of Oregon, oysters are another species that have been seriously affected by the increasing acidity in oceans. And for a number of years in a row, the oyster hatcheries in Oregon had failure year after year after year. The young were not -- they were not able to raise the young. They grow the larvae, the young in tanks and then creates the spat than then oyster growers will out plant and they were having failures year after year.

Scientists working with the oyster hatcheries figured out that the problem was the water was too corrosive, it was too acidic for the larvae, and they were just not able to make a go of it. They figured out a short-term solution for that because this is in a tank situation so you can do something to ameliorate it. But it appears to be a harbinger of things to come with more species reacting negatively to this increasing acidity. Some of the other experiments that have been done in laboratories suggest that some species can cope, for example, baby sea urchins can cope fine with increasing acidity or with increasing temperature but not both of them. And, of course, in the real world, they're happening together.

The one ocean acidification sort of story that a lot of people are very concerned about has to do with coral reefs and corals are very, very sensitive in the tropics. They're very, very sensitive to changes in ocean chemistry and especially in laboratory conditions many species of corals are unable to continue to make their skeletons of calcium carbonate and they are -- the predictions that have been made is that by mid-century, sort of growth of corals will seize. And by the end of the century, we won't have active coral reef formation.

So it's actually something that is of great concern because coral reefs cause this three-dimensional habitat for the rainforest of the sea. All these homes this wonderful three-dimensional structure for fishes for all of the other marine life that live in this structure that they've created. So osteoporosis

of the sea is the moniker that some people have given to ocean acidification.

Greg Dalton: I took my then 10-year-old son scuba diving once in the Bahamas and just realize that he'll be able to talk about the disappearance of that probably in his lifetime. But more directly that impacts the many, many subsistence fishermen in Indonesia and around the world who rely on fish beneath that coral. And what that means for ecosystems and economies, people who are living close to nature, what are the impacts of that?

Jane Lubchenco: That is likely to be a very serious consequence to people and especially when you think about the fact that between one billion and three billion people are depending on seafood for their primary source of protein, and a large fraction of those are in the developing world. Indonesia, for example, 60 percent of Indonesians depend on seafood for their primary source of protein and a lot of that is artisanal fishing and it's dependent on the reefs. And so they may very well be some very serious consequences not only to that, which in fact is a real food security issue, but also in terms of livelihoods for tourism. And, of course, coral reefs are spectacular places for tourists to visit.

Greg Dalton: Jane Lubchenco is a former administrator of the National Oceanic and Atmospheric Administration. We're talking about climate impacts on oceans and the atmosphere at Climate One. I'm Greg Dalton.

Now, that we've taken you down deep into the dark ocean, let's talk about the ways out, the solutions, the solutions for this and some of the rays of hope that you see for a different path forward. Let's start with Ben Santer in terms of what the solutions are and what the prospects are for averting some of this impact we've talked about?

Ben Santer: People often ask me, "How can you go into work in the morning? Aren't you profoundly depressed? You know what the likely outcomes are and where are those rays of hope that make your life bearable." And for me, one of the answers to that kind of question is that, over my lifetime as a climate scientist, I've seen these twin signals. One is this signal in the physical climate system warming of the ocean, warming of the land surface, warming of the atmosphere.

But in tandem with that physical signal, I think there has been a signal in public understanding. We've move from 20 years ago we don't really know whether it's warming or not to warming is unequivocal. We've moved from 20 years ago we don't really know much about causation here to most of the observed change of the second half of the 20th century in global mean surface temperature is extremely likely due to human intervention in the climate system. We've moved from denying the science to informed discussions on what to do about it.

That makes me extremely hopeful, actually, that people who never would have listened to me, even five years ago, are now willing to give me 30 minutes of their time to listen to the science pure, unvarnished account of what we know with confidence, what we don't know, and why they need to care about it. That makes me hopeful. This makes me hopeful, Climate One. This is a safe place where people with very different perspectives on the science and the solutions can have a discussion on the what to do about it?

It makes me hopeful that we have things like Kyoto. We have things like Copenhagen. We have these meetings where even though nations go in with tremendous differences in national self-interest, they're sitting at the same table. They recognize that this is a serious problem -- incredible problem. We need to do something about it.

For all of those reasons I'm hopeful. I'm not so knowledgeable on the solution side of things but I do

think that as Steve would have put it this false dichotomy, "You can either preserve millions of American jobs or do something about climate change." It's just that false. The reality is that individuals, companies, countries who figure out cheap, efficient ways of providing low-carbon energy are going to be the leaders of the 21st century, and we have a real choice here in the United States, either to be leaders in that endeavor or to be followers. I hope we're leaders not followers.

Greg Dalton: Jane Lubchenco, when you went into the National Oceanic and Atmospheric Administration, you talked about the green economy. Did that happen as much as you anticipated that this hope that Ben Santer talked about? Because the National Oceanic and Atmospheric Administration is part of the Department of Commerce, I've studied this quite a bit, I can't point to one thing or what the Department of Commerce has done in this area. Lots of other parts of the federal government I can point to things. So let's talk about the Obama record there.

Jane Lubchenco: We've talked a lot about tipping points and I think that there are tipping points in people's behavior and understanding as well as tipping points in the physical system that is the biophysical system that's the climate system. Things that I think the president has got in climate, he's very concerned about it. He's long been concerned about it and has wanted to do a lot more than he was able to do with the Congress that just has no appetite for dealing with climate.

And so the president has proceeded to do through executive orders and executive actions through the agencies, actually a very impressive series of achievements. The standards for appliance efficiency, fuel economy standards, the agencies are moving ahead with very ambitious plans to reduce their own greenhouse gas emissions.

And on the international front, I think there has been very significant progress made in some surprising arenas, for example, in agreeing or putting on the table the need to use to limit some of the greenhouse gases that are now allowed under the Montreal Protocol that, in fact, are greenhouse gases and are not only -- well, and to limit them through the Montreal Protocol and these are hydrofluorocarbons which are allowed. But because they are damaging or they are greenhouse gases, it is possible to regulate them through the Montreal Protocol but China and India have not been, until recently, willing to even talk about that.

The president and the president of China, this summer, announced that they think this should happen. They talked about it at the G-20 meetings. The president is having discussions with India on the very same issue. And so that's an international activity that although it hasn't come to completion is very encouraging and very positive. And, in fact, would have a very significant impact. It's in addition to the need to have actions in this country that are regulating carbon. So I think that whole portfolio of activities is, in fact, achieving some very good things. I think there's just a need to do a lot more and a lot faster.

And to sort of connect back to the tipping points, the extreme weather that a lot of people are seeing is changing opinions. I think that that's helpful. Many more people are beginning to see climate not as an economic issue, not as a political issue but as a moral issue. Not only our obligation to other people in the world but to future generations and to all of life on earth. And changing the way we think about the problem, I think, is part of the solution. So I, like Ben, see some reason for hope. It's just frustrating that we aren't farther along because we see that there is real urgency in moving ahead with this.

Greg Dalton: Ben Santer?

Ben Santer: Yes, if I might add to that briefly. In my public speaking on climate change, I now preface my talks by showing pictures from mountain ranges around the world and the climber -- I've

been a climber since I was 18. And over one human lifetime, I've seen profound changes in these fragile high alpine places. Some of the glaciers I stood on in the Alps, as a young man, are halfway gone. A couple of years ago, I had the privilege of being at Camp 18 in the middle of the Juneau Icefield. When you stand up there and climate change is not some academic thing, it's pervasive. You see the signs of change everywhere.

To me, in addition to the scientific imperative to understand the human contribution to these changes, there is an important moral and ethical imperative too. It's profoundly sad that future generations may not experience the coral reefs or these fragile high alpine environments in the same way that we did and we've experienced these changes over a human lifetime.

Greg Dalton: So putting this moral lens on it, does that mean I'm immoral if I fly an airplane and taking a discretionary trip? Does that mean -- I'm trying to translate that because putting up moral is a very high bar.

Jane Lubchenco: It is.

Greg Dalton: It's very polarizing. In our society, the moral issues abortion, et cetera, that gets people worked up as I'm right and you're wrong. So am I immoral for taking a plane ride?

Jane Lubchenco: So I think that is a very great discussion that we need to have collectively and I think if you -- for people who have gotten into calculating their greenhouse gas footprints and figuring out what they need to do to reduce it. So it's not a single action like a single plane ride but it's the collective actions. And not only what individuals do but what corporations do, what cities do, what communities do, and think about all the different ways to reduce that footprint.

Now, one of the things that I really came to appreciate spending four years in Washington D.C. was the importance of incentives. And there is the moral argument on the one hand and I think that's a very important one but there's also incentives for people to change behavior. And what I think we need is changing the incentives that will make it more likely for Congress, for example, to deal with to provide the appetite, if you will, to tackle, some call it, climate legislation.

And that's one thing that Senator Whitehouse has been talking about as a potential benefit of having -- regulating fossil fuel power plants, both the new ones and existing ones under EPA regulations. And he has hypothesized that that has a great likelihood of, in fact, changing the incentive equation for businesses, and that they in turn will turn to Congress and say, "Hey, we need some help here. We need some certainty. We need to get something done. Give us some help. Deal with this." And so changing incentives and having the moral arguments and the moral discussions and seeing it as a moral issue, I think are part of the portfolio that is very timely.

Greg Dalton: What can an average person do whose thinking about this? Maybe they've changed their light bulbs, maybe they have a plug-in or a hybrid car, but what can an average person do while we're waiting for Congress to do that?

Jane Lubchenco: Well, many people have done that and many communities have done that. And, in fact, I think that's very encouraging and very positive. We need that to happen not only in California and Oregon and Washington but across the country. The interfaith power and light communities of congregations all around, lots of different faith-based groups are tackling this issue in many states on issues that are in their own communities. That's something very active. People can work together with like-minded individuals to work on reducing carbon emissions.

Be politically active. Pay attention to what your elected representatives do. Help school kids

understand what's happening. One of the things that also gives me hope is the number of young people that are very concerned about this issue and really want to change it.

Greg Dalton: Ben Santer, what can an average person do?

Ben Santer: Inform yourself about the science. I think that if we are to take smart decisions on the what to do about all of this, we need an informed scientifically savvy electorate. So I think that's part of the valuable role that Climate One fulfills, providing good information, not only on the underlying science, but also on the what to do about it? And I think that's the best single thing that you can do is really be knowledgeable about these issues.

Because ultimately, to get back to the wit and wisdom of Harry Potter, there will come a time when we must all decide between what is easy and what is right, and we're approaching that time where we have to decide whether which is going to follow the path of least resistance in terms of emissions of greenhouse gases, or whether we're seriously concerned about the kind of world we want to leave behind for our kids and grandkids.

So having some knowledge of the likely outcomes, what is the climatic shape of things to come for sea level, for temperature, for rainfall, for extreme events, for their statistics, their intensity, their frequency? In the end, that basic knowledge and that interest in the science I hope will enable us to do what is right, not what is easy.

Greg Dalton: We're talking about climate impacts at Climate One. I'm Greg Dalton. Our guests are Ben Santer, a scientist at Lawrence Livermore National Laboratory; and Jane Lubchenco, former administrator of the National Oceanic and Atmospheric Administration.

We're going to now invite your participation. And if you're over on this side of the house, please come over to the microphone. Go through those doors back there. Here, you can stand up. The line forms right there with our producer, Jane Ann. We welcome your one-part comment or question. I'll help you keeping them brief and on track. And this is often one of the most lively and dynamic part of our conversation. Don't be shy. Usually the first one gets it rolling. Let's go to audience questions. Welcome to Climate One.

Holly Kauffman: All right. Thank you for having yet another wonderful Climate One evening. I'm Holly Kauffman and my question is, it was my understanding that during the recent sequestration budget cuts that we were going to be losing some important weather and climate observation satellites, could you explain to us the importance of those satellites and what the status is whether we have them or not? Thank you.

Jane Lubchenco: Did everyone hear the question? There are series of satellites that fly that are equipped with either weather and/or climate instruments that give us information that's invaluable that allow us to predict the weather as well as track climate change. Some of those satellites are operated by NOAA, National Oceanic and Atmospheric Administration. Others are operated by NASA and some by some other agencies but those are the two main players here.

When I went to NOAA in beginning of 2009, we had inherited a weather satellite program that had been dysfunctional for many, many years. It had real serious management problems because of the way it had been structured. The satellites that are in space now are doing a great job of providing scientific information that allows us to predict the weather. And over 90 percent of the data that go into the weather models come from satellites. So it's critically important that we have those satellites.

We fixed the management of that program and then had to get the resources from Congress to continue building these weather satellites. Our intention was to have climate instruments on those satellites as well as weather instruments. The program has become more and more expensive through time and it's been a real challenge to get it funded at all. I was on the hill talking to members of Congress about how important these weather satellites where we would fix the management problems and one member of Congress said to me, "Doctor, I don't need your weather satellites, I've got the Weather Channel."

[Laughter]

Jane Lubchenco: And I thought, "Boy, do I need to take a few steps back and start all over again?" Now if it's that hard to get weather instruments funded and weather satellites funded, it's a lot harder to get instruments -- climate instruments on satellites. And the budget cuts have actually created some real havoc with the satellite programs and it's delayed them, which increases the likelihood that there will be a period of time where we won't have that coverage, and will be able to do weather forecast that are sort of the quality that we had 30, 40 years ago, not the quality that we have today. And there's real danger that many of the climate instruments are not going to be funded and not going to fly on satellites and it's an economic issue.

In other words, it takes dollars to do it. But the problem began before the shutdown, before the sequestration but those have exacerbated it. And as we look ahead to stabilizing federal funding, it's really important that we pay attention to funding sources for those climate and weather instruments because they're both incredibly important.

Greg Dalton: Another casualty was the CIA created an office on climate that was shutdown as one of the victims of some budget battles. Let's have our next audience question. Welcome to Climate One.

Anne Arquit: Thank you. My name is Anne Arquit. I have a two-part question. Do you think that we're on track to stay within the two degrees centigrade warming that sort of has a political and scientific consensus that that's sort of a safe level for the planet? And if not, what level might we be able to achieve? And the second part of the question is, what are the scariest impacts that are coming out of the IPCC report next year that we should be really worried about if we don't make two degrees?

Greg Dalton: Two degrees is a number that countries have agreed to through the Celsius. Ben Santer, help us. That's how many three and a half Fahrenheit or something? So --

Male Participant: 3.6.

Greg Dalton: 3.6? Thank you.

Ben Santer: Yes. People have struggled with this idea of defining a level of global mean temperature change beyond which we would risk dangerous anthropogenic interference, as it's called, in the climate system and we don't really have a good handle on what that number is. People have come up with a number 2. Others suggest that it's lower than that, perhaps even 1 degree Celsius relative to the end of the 20th century. We don't really understand how close we are to some of these tipping points that we discussed a little earlier and at what point we go over the cliff?

So in answer to your question, there are a lot of things that are of concern. Jane mentioned ocean acidification, that's real. It's happening now already. There's concern about that. The warming of the Arctic, the falling of permafrost, release of methane to the atmosphere from high latitudes in the

Arctic, that's a concern.

There are concerns, as Greg mentioned, about changes in the ocean circulation in the North Atlantic. Perhaps Wally Broecker said it best, "Climate is an angry beast and we're poking it with a sharp stick." We don't really know very well where that level of dangerous anthropogenic interference is and are unlikely to do so for a number of years. So it's all about risk management. What level of risk are you prepared to accept for some of these bad things to happen? That's what it boils down to.

Jane Lubchenco: Greg, could I add to that.

Greg Dalton: Sure.

Jane Lubchenco: I think there are two other issues that are worth flagging about things to be concerned about. One, it has to do with food, agriculture in particular, and I think that for a long time folks thought fairly naively that ag was no big deal because planting zones would just move toward the poles and everything would be fine. But I think there's increasing reason for concern because of droughts, changing precipitations, changing patterns of precipitation and heat waves and those are wreaking havoc with the food supply, food-growing regions.

The second area is more in the realm of international security issues because of disasters in other parts of the world causing ramifications that have real consequences to Americans. This is an American-centric way of thinking about things. But the Department of Defense has been very focused on taking climate seriously and seeing it as an issue they have to deal with. And preparing for climate change, focus on the Arctic but focus on increasing disasters around the world, civil strife and other humanitarian disasters such as Typhoon Haiyan and other things causing problems that they will then have to deal with. So seeing it more as a national security issue and I think there's increasing concern that that's very real.

Greg Dalton: We have a long line of questions. Let's try to get through as many of them as we can in the remaining 10 minutes. Welcome to Climate One. Yes?

Male Participant: Thanks. In 2007, China surpassed our carbon emissions. In the next year or two, they're going to be double for carbon emissions. At the same time, the U.S. has reduced its emissions surprisingly by about 12 percent. How do we help China and India reach the same standard of living that we have without destroying the world in the process?

[Applause]

Greg Dalton: Climate justice.

Jane Lubchenco: Yes. So I think the good news is climate -- I mean China is actually taking this very seriously though it's an issue that they care about. And even though they are building power plants, coal-fired power plants at just a breakneck speed, they are also very concerned about some of the consequences, some of the immediate health consequences with air quality but it goes beyond that and in terms of climate and I think there's increasing awareness by the leadership in the country that it's a very real problem that doesn't mean that there are obvious solutions.

Greg Dalton: The elite is definitely being affected by the air pollution. Let's have our next question. Welcome to Climate One.

Ashley Cryan: Thanks. My name is Ashley Cryan and I'm curious to know what your opinion is on geoengineering in relation to climate change and what the potential might be for a technology to

play a part in some of the solutions? Thanks.

Greg Dalton: Geoengineering, break the glass, pull the switch. Ben Santer?

Ben Santer: Geoengineering has received a lot of attention in the last five or six years. The idea being that we can intervene in the climate system that we can do something to counteract the warming caused by human-induced changes and levels of greenhouse gases in the atmosphere. To me, speaking personally, that's always seemed a little problematic. We're already engaged in what Roger Revelle called a grand geophysical experiment, and we can't claim ignorance anymore. We know that we're no longer innocent bystanders. We know that we've changed the chemistry of the earth's atmosphere and we know the likely consequences of those changes.

So the idea of doing a second intervention to counteract the effects of the first intervention seems a little problematic to me. I remember I first encountered this at Lawrence Livermore National Lab about 15 years ago. Edward Teller invited me into his office and wanted to talk about geoengineering. He had the idea that one could inject essentially sulfate aerosols into the stratosphere and reflect back some portion of incoming sunlight and counteract human-caused warming

I pointed out that after big volcanic eruptions like Mt. Pinatubo in the Philippines in 1991, scientists observed that these aerosol particles formed surfaces on which some interesting chemistry took place that was responsible for the -- partly responsible for the depletion of stratospheric ozone and depleting stratospheric ozone would be a bad outcome. That's not something we want to do. So to me, as a climate scientist who spent much of his career trying to understand the first geophysical experiment that we are doing and recognizing the complexities involved in trying to project the outcomes of this first experiment, I would not like to put all of my eggs in the geoengineering basket and say, "We are confident that we know enough to find a technical solution."

That being said, I do think that it's important to do some of the research now and understand if things get really dire, if human-caused climate change is worse than our current model projections, we have some understanding, at least, of different intervention strategies and their likely outcomes. And many people around the world are now doing that research. I sure hope we don't have to do it in earnest in the real world.

Greg Dalton: Next question, welcome to Climate One.

Female Participant: Hi. My question is what do you feel are the top like three things we should be pushing our legislators to pass to reduce our carbon emissions?

Greg Dalton: Jane Lubchenco, top three?

Jane Lubchenco: I think the big one that is on the table or that's off the table that needs to be on the table is some kind of legislation that either puts in place a cap-and-trade system or a carbon tax system.

[Applause]

Jane Lubchenco: But the likelihood of that happening in this Congress is not very great. So that's really the biggie. And I think the question is more how do we get to that point where it is something that can be talked about and how do we change the minds -- either change the people or change the minds of the people who are there and it's one or the other.

[Applause]

Greg Dalton: Let's have our -- thank you for that question. Let's have our next question at Climate One.

Male Participant: Sounds like the biggest problem America has is ignorance in Congress and I don't think you're going to alleviate that. But as I conjure about a common plate this situation, it came to mind that money is a major player in this. Why don't we incorporate the drug runners and using Bitcoins to finance the research tools that you need to have. And that's not a joke. There's a lot of drug money out there and it's sitting offshore and they're using Bitcoin, so why don't we incorporate that and just go around Congress and their ignorance.

Greg Dalton: Cannabis and carbon. Jane?

[Laughter]

Jane Lubchenco: I'm not sure I know how to react to that.

[Laughter]

Greg Dalton: Welcome to San Francisco.

[Laughter]

Female Participant: My name is Vero and thank you very much for an incredible program. My question is around we have such an incredible opportunity influence organizations internationally and my question is, are there equivalent of NOAA organizations around the world, and where are they, and how do we influence them, and how do you interact with them?

Jane Lubchenco: The federal agency, NOAA, has responsibility for a broad suite of things, weather, climate, oceans, fisheries, coasts or sort of the lay of the land. And there are indeed a number of really outstanding agencies in other countries. NOAA deals directly with a lot of its counterparts, its sister agencies in the UK, for example, and in Europe as well as Japan but also lots of other countries around the world, and they have a lot in common that's based on science and they trade information so there's a whole community around each of those different issues that might not be all in a single ministry or agency. But, in fact, there is a lot of active trading of information in a way that benefits everyone.

One of the real challenges that I faced when I was at NOAA that is only becoming worse is that there is some suspicion by some members of Congress that anything that's international is bad and the international travel is a boondoggle. And for scientists to go to meetings to trade information to stay current or for the leaders of the agencies to go and meet with their counterparts and talk about, "Let's work on this satellite system together. We'll co-fund it so that we all benefit because satellites are expensive and we'll put our instruments on it, your instruments." We have that kind of deal with a number of other countries. That's not seen that kind of travel to do that kind of discussion is actually increasingly problematic in this Congress.

Right now, the administrator of EPA is in China and she's talking to her Chinese counterparts about these kinds of things and she is being very strongly criticized by members of the administration. There's actually legislation that has been written that says that she may not travel to other countries until she's visited every single state in the U.S. that's a major coal-producing state, and she has to talk to them first and understand their perspectives before she goes to other countries. So those are some of the international challenges that, as I said, are just becoming more and more crazy.

Greg Dalton: Ben Santer, really quickly. We'll get one last question. We got to wrap it up. Ben?

Ben Santer: Sure. Quickly, over my lifetime as a scientist, the sharing of computer model simulation output has changed fundamentally. Twenty years ago, individual computer modeling groups perform some numerical simulations and held on to that simulation output for years.

Now, we have the ability. Everyone in the room has the ability to interrogate the results from all the world's climate models. It's a fundamental game changer. Essentially, the enterprise of computer modeling of the climate system, the results from those simulations that have been performed by dozens of groups around the world are freely available to anyone and that's enabled a lot better science.

Greg Dalton: Very quickly.

John Berendt: This afternoon at the American Geophysical Union, they had a session on abrupt climate change. Would you explain to the people here what is meant by abrupt climate change and how important is it?

Greg Dalton: Ben Santer, how could things change, very quickly?

Ben Santer: Abrupt climate change, as I understand it, is something like a sudden change in that conveyor belt circulation that we mentioned in the North Atlantic, an abrupt release of methane to the atmosphere, things that happened on time scales of years to decades that have consequences for much longer periods of time.

Greg Dalton: We've been talking about disruptions on the earth's atmosphere and oceans at Climate One at the Commonwealth Club. Our guests have been Ben Santer, a scientist at Lawrence Livermore National Laboratory; and Jane Lubchenco, a distinguished professor of Marine Biology at Oregon State University and former administrator of the National Oceanic and Atmospheric Administration. I'm Greg Dalton.

Thank you all for listening and coming to Climate One today.

[Applause]

[END]