Changing Planet: Past, Present, Future
Lecture 4 – Climate Change: How Do We Know We're Not Wrong?
Naomi Oreskes, PhD

1. Start of Lecture Four (0:16)

[ANNOUNCER:] From the Howard Hughes Medical Institute...The 2012 Holiday Lectures on Science. This year's lectures: "Changing Planet: Past, Present, Future," will be given by Dr. Andrew Knoll, Professor of Organismic and Evolutionary Biology at Harvard University; Dr. Naomi Oreskes, Professor of History and Science Studies at the University of California, San Diego; and Dr. Daniel Schrag, Professor of Earth and Planetary Sciences at Harvard University. The fourth lecture is titled: Climate Change: How Do We Know We're Not Wrong? And now, a brief video to introduce our lecturer Dr. Naomi Oreskes.

2. Profile of Dr. Naomi Oreskes (1:14)

[DR. ORESKES:] One thing that's really important for all people to understand is that the whole notion of certainty is mistaken, and it's something that climate skeptics and deniers and the opponents of evolution really exploit. Many of us think that scientific knowledge is certain, so therefore if someone comes along and points out the uncertainties in a certain scientific body of knowledge, we think that undermines the science, we think that means that there's a problem in the science, and so part of my message is to say that that view of science is incorrect, that the reality of science is that it's always uncertain because if we're actually doing research, it means that we're asking questions, and if we're asking questions, then by definition we're asking questions about things we don't already know about, so uncertainty is part of the lifeblood of science, it's something we need to embrace and realize it's a good thing, not a bad thing. and if somebody comes along and says "Well, you know, evolution is very uncertain," you can say, "Well, of course it is, all life science is uncertain," but the fact is that there are some parts of it that are extremely well established. There are some parts for which the evidence is so robust and so strong that it would be silly to dismiss it. And that's the same with climate change, and that's really my message for ordinary people, citizens, students, teachers: there's a lot about the climate system that we don't know. But there is an awful lot that we do know, and we know, we know that the Earth's climate is changing right now, it's changing in front of our eyes, it's become so obvious that you can't really deny that changes are underway, but we also know that those changes are driven by human activities and that's the part that we need science for because that comes from our basic understanding of physics and chemistry, and that certain gases trap heat in the atmosphere, and when you put more of those gases into the atmosphere, you trap more heat and that heat warms the planet and that's basic physics, that's high school physics and chemistry, that's something that any person who's graduated from high school in the United States of America can understand and should understand, and anybody who tells you that that's uncertain, is either very confused or they're lying.

3. Why climate change matters (3:24)

[DR. ORESKES:] It's great to be back again. I'm happy to have the opportunity to bat cleanup and to talk to you a little bit more about this very important question of climate change, both what the science is, and also this question of why so many people have been resistant to the scientific evidence on this extremely important issue. So as I explained to you in the first lecture, I'm a historian of science, so in the last several years I've been studying climate science, studying how climate scientists have tried to understand the Earth's climate system, how they've come to the conclusion that the climate is changing, and how they've come to the conclusion that those observable changes are being driven, to a very great extent, by human activities. But I'm also a citizen and I care about climate change because of what it's doing now, not what it's going to do to the planet in 10,000 years. I agree 100% with Professor Schrag: the planet will be fine. It's about what's going to happen to us living on this planet now and over the next 50, 100, 200 years and I'm especially concerned about it because of things that I care about and love and one of those things is skiing. So about a year ago I was invited to serve on the board of a non-profit organization called Protect Our Winters. In a moment I'm going to show you a video about it. I just want to say a couple of words about Protect Our Winters. So Protect Our Winters was founded by professional snowboarder Jeremy Jones. When Jeremy asked me to join, he sent me the materials, there was this big 8-1/2 by 11 glossy of Jeremy, and my 17-year-old daughter Clara looks at this picture and she goes to me, "Mom, you HAVE to join this organization." Jeremy is an incredible guy. He is an absolute stud and he's also passionate about climate change.

4. Video: Protect Our Winters (5:06)

We're going to show you a video now that talks a little bit about why Jeremy Jones founded Protect Our Winters in response to what he was seeing himself, as a professional snowboarder, watching to what was happening to snow and ice around the globe. Let's roll that video now.

[JONES:] I started to see the mountains changing, and I felt like we needed to, as a group, as a winter sports enthusiast, I felt like we're the ones on the front lines, we see the change, and it's important for us to try to make a difference and protect our playground.

[JONES:]When I started Protect Our Winters, the last thing I wanted to do was, like, get into this political side of things. But it became really apparent to me that in order to really move the needle in climate change that it needs to be won on Capitol Hill.

[JONES:]Putting on a suit is, uh, you know, definitely different than I normally roll.

[to camera] I hear we're going to Capitol Hill so I brought some hiking shoes.

[JONES:]People definitely don't have long hair in Washington.

[JONES:]The reaction we received on Capitol Hill was open arms, we need your help, keep doing what you're doing, collectively you guys have a very strong voice, a much stronger voice than you think.

[DR. ORESKES:] So that's Protect Our Winters. I'd encourage all of you to check us out on the website protectourwinters.org. So Jeremy and Chris Davenport and Gretchen Bleiler and the other snowboarders and skiers in this organization are all seeing climate change happen in front of their eyes, but they're athletes, they're not scientists and they can't explain exactly what's happening. They can't explain why it's happening and for that we turn to science.

5. Science, politics, and the acknowledgement of rising CO2 (7:03)

So how do we know that the climate is changing? What is it that we've learned about this? Well, the fact is that scientists have known about climate change for a long time and our political leaders have known about it for a long time too. When Dave Keeling first started measuring carbon dioxide in 1957-'58-- Dave was a colleague of mine at the University of California, San Diego-- it just took a few years for him to conclude that indeed there was evidence that carbon dioxide was already increasing. And he and a group of other scientists wrote one of the earliest reports trying to explain why this might matter to the American people. And we know that that report was actually read in the White House under President Lyndon Johnson and in 1965 President Johnson said to Congress, "This generation has altered the composition of the atmosphere on a global scale through a steady increase in carbon dioxide from the burning of fossil fuels." So this is really very old news. Now it's not just Lyndon Johnson though. By 1979 the U.S. National Academy of Sciences had concluded that "a plethora of studies from diverse sources indicates a consensus that climate changes will result from man's combustion of fossil fuels and changes in land use." So by 1979 we knew that carbon dioxide was rising and scientists were trying to communicate that this rise in carbon dioxide was going to change the climate. By 1990, our first President Bush, President George H.W. Bush said, "We all know that human activities are changing the atmosphere in unexpected and unprecedented ways." And then in 2001 the IPCC: "Human activities are modifying the concentration of atmospheric constituents... that absorb or scatter radiant energy. Most of the observed warming over the last 50 years is likely to have been due to the increase in greenhouse gas concentrations." And of course, the Keeling curve, CO2 rising and rising and rising. And then finally, most recently, the fourth assessment report of the IPCC 2007, as carbon dioxide was pushing above 380 towards 390 and even 400 parts per million: "There's very high confidence that the global average net effect of human activities since 1750 has been one of warming."

6. Many Americans remain unconvinced of climate change (9:18)

So what the history tells us is that, while Dave Keeling was tracking the steady rise in carbon dioxide, there was also a steady rise in the attempts by scientists to communicate to the American people and our leaders and the international community what was happening and why it mattered. And yet despite this 50 years of scientific research and 50 years of scientists trying to communicate to all of us about the issue, the American people remain confused and divided about the reality of global climate change caused by human activities. Polls are fickle. The American public changes its mind a lot, but over the last 10 to 15 years, polls have consistently shown that only about half of us understand the scientific evidence and accept that the climate is changing and it's caused by our activities. At least 25 to 30% of us reject that scientific information, doubt that climate change is even happening, or if we accept that it's happening, we doubt or disbelieve that it's caused by our own activities. So there's a big gap between what the scientists have been telling us and what we, as the] American people, have been hearing. Polls also show that Americans are less concerned about climate change than people in almost any other place on Earth. So even in China people are more worried about climate change than we are here in the United States. Now that may have changed after the events of the last two years, but it's still a very serious issue.

7. Providing knowledge does not always lead people to act (10:44)

Now in response to this the scientific community has sometimes suggested that we have what they call an information deficit. That is to say that the reason we're confused and divided on this issue is that we don't understand the science. We haven't received enough good information communicated clearly, and so therefore the scientific community needs to do more to explain this problem to the American people. So the scientific community has responded to this perceived information deficit by trying to create an information surplus, by increasing K-to-12 science education, through public outreach and informal education efforts in museums and aquaria and planetaria around the country, through statements that you can find on the Internet, on webpages of the scientific societies, through improving the scientific estimates of uncertainties that we can speak in a clearer and less ambiguous manner, and even things like the Holiday Lectures at the Howard Hughes Medical Institute. But the evidence, the empirical evidence suggests that these efforts have not really had an impact. There has been tremendous increases in education and outreach on climate change over the last five years or so, but it has not led to broader, more widespread understanding and acceptance of the scientific conclusions. Moreover, if we think about it, we actually have a number of other examples that suggest to us that the information deficit model is insufficient, that simply being provided with information does not necessarily lead people either to understand it, much less to act upon it. The most obvious example of this has to do with smoking tobacco. Scientists have known for more than 60 or 70 years that using tobacco is extremely harmful, that smoking tobacco kills you, it causes a host of disease, not just lung cancer but heart disease, emphysema, bronchitis, bladder cancer, pancreatic cancer, blindness. The list of diseases related to tobacco use is extremely long, and yet despite the fact that this knowledge has been around for a long time, we see that global cigarette consumption has continued to increase even today as we speak. Another example closer to home involves obesity. Scientists have known very well for at least 20 or 30 years that being overweight is bad for your health and that being very overweight, being obese, can kill you. And yet despite very extensive scientific evidence on this question, if we compare the obesity rates in the United States in 1985 to what they look like today, we see a dramatic increase in obesity, despite tremendous amounts of evidence that it's bad for our health. So there are, of course, many reasons why people may be overweight, there are many reasons why people might smoke cigarettes, but at least these data show us that simply giving people knowledge is not enough to lead them to act.

8. The origins of organized denialism (13:41)

So given this information, my colleague Erik Conway and I, who have worked on this together for about six years now, have suggested that there must be some additional explanation for why people have rejected climate science. And there are many reasons. It's not simply one thing. But our research has focused in particular on something we think is extremely important to understand. And that is the fact, the historical fact, that there has been, over the last 20 to 25 years in the United States, organized resistance to the scientific evidence: an organized attempt to challenge and cast doubt upon the scientific claims of people like Professor Schrag and Professor Knoll who you've just heard from. So in our research we asked the question. So where did this organized resistance come from, and through historical research we were able to track it back to its origins and discover that it actually had its origins in one particular place; a think tank here in Washington D.C. named the George C. Marshall Institute. This think tank was founded by three prominent American physicists shown here: Bill Nierenberg, Frederick Seitz, and Robert Jastrow; all of whom were highly distinguished, prominent physicists who had worked on Cold War weapons and rocketry programs. Bill Nierenberg had helped to build the atomic bomb, Frederick Seitz had helped to build the hydrogen bomb, and Robert Jastrow had helped to build the Apollo space program. Over 20 years these scientists challenged the scientific evidence on a host of issues, including stratospheric ozone depletion-- the ozone hole; the reality and the causes of acid rain and other forms of acid precipitation; and the harmful effects of tobacco.

9. The history of the Marshall Institute (15:26)

So you might ask the question, why would scientists challenge the work of their fellow scientists, and in particular, why would physicists challenge the work of climate scientists, and why would physicists defend tobacco? Well, the story begins with something that seemingly has nothing to do with climate change or tobacco or any of these issues-- the Strategic Defense Initiative. Now this, of course, is before any of you were born, but you may have heard of the Strategic Defense Initiative. It was sometimes also referred to as Star Wars, drawing on the name of the film of the same name, because it was based on the idea of weapons in space. This specific idea was to create a network of ground and space-based lasers that would defend the United States against incoming intercontinental ballistic missiles. That is to say, to defend us against a nuclear attack by the Soviet Union. Now it was a very controversial program, it was promoted and pushed by the Reagan administration in the early 1980s, but it was very controversial among scientists. The vast majority of American scientists criticized the program as being technologically unfeasible and politically destabilizing, because if you built a missile shield and you thought that you could protect yourself against a retaliatory attack then you might be tempted to launch a first strike. You might be tempted to say, let's take out those Soviet missiles because if they strike back, if that empire strikes back, they won't be able to hurt us because we have a missile shield. So a lot of scientists thought it was a bad idea because it might in fact tempt the United States to launch a first strike and start World War III. But some scientists, a very small minority, but some distinguished scientists defended SDI as necessary to protect the United States from the communist threat. And the three men who led that defense of SDI were Bill Nierenberg, Fred Seitz, and Robert Jastrow. They created the Marshall Institute for this purpose; to defend the Strategic Defense Initiative against the criticism of it by other scientists, other people in the scientific community. Now that was in the early 1980s, but in 1989 something surprising happened, something that not very many people anticipated: the Cold War ended. The Berlin Wall fell down and the Soviet Union broke apart, so the U.S. won the Cold War. So you might have thought that these men would be happy, that they would have retired to go play golf, because by now they were in their seventies and even early eighties, but they didn't retire. They kept on fighting and they took up a new cause. And the new cause was the continued defense of capitalism, of free-market capitalism, but not against the communist threat, not against the Soviet threat, but against what they thought were enemies within, what they considered to be an internal threat. And that was a threat they believed to capitalism as a form of freedom.

10. Government regulation as protection against harmful activities (18:29)

And the argument focused around the question of government regulation. Government regulation has been used historically both in the United States and throughout the world to protect people, to protect citizens and the environment from the true costs of harmful products and harmful business activities. But some defenders of free-market capitalism resist government regulation because they fear that it will head in the direction of socialism and lead to a loss of personal liberty. The most famous example, in fact, involves tobacco. So let's think a little bit about tobacco smoking. If you smoke cigarettes you do it because you find it enjoyable and pleasurable but it could kill you, and that's a pretty big cost. Moreover it's not just that it might kill you. You might decide, I'm willing to take that risk because I like smoking, but it turns out that smoking cigarettes can kill the person sitting next to you too. It can kill the waiter in the restaurant who is serving you. It can kill your bartender and perhaps most worrisome of all, it can kill your spouse and your children, because we have overwhelming scientific evidence that the children and spouses of smokers also have elevated rates of lung cancer and other smoking-related diseases even if they never smoked themselves. So those are all costs of cigarette smoking. But when you buy a pack of cigarettes, the price of that pack of cigarettes doesn't reflect those costs. But society has an interest in preventing those costs. In particular we have an interest in protecting children, and so for this reason, we began in the 1950s and 60s to tax and regulate and in some cases, ban cigarette smoking. Well, we also have an interest in preventing ozone depletion, because ozone depletion can lead to deaths through increased exposure to ultraviolet radiation. We have an interest in preventing acid rain, because acid rain can destroy forests and lakes and kill fish, and also do damage to historic monuments and buildings and bicycles. And we have an interest in preventing climate change. You saw Professor Schrag's maps of what a three meter sea level rise will do to major metropolitan areas in the United States and elsewhere. So how can we prevent these harms? Well, we can prevent them in a variety of different ways. In the case of tobacco we largely discourage the use of tobacco through heavy taxation. We made the price of tobacco reflect some of those other additional costs, so in a sense we can say we put a price on the social cost of tobacco. We also limited advertising and in some cases we've banned cigarette smoking, such as on airplanes or in restaurants, which we did first in California, I might say. In the case of acid rain we controlled acid rain through an emissions trading scheme put into place by the first Bush administration under the Clean Air Act. And in the case of ozone, we took steps to protect the ozone layer through an international treaty to ban the chemicals that were causing ozone depletion. But every one of these actions was a government intervention in the marketplace and every one of these actions did, in fact, put some limits on business activities and personal freedom. You cannot smoke a cigarette in an airplane even if you think that you should have the freedom to do that.

11. Think tanks and scientific denialism (21:51)

Well, the Marshall Institute opposed all of those forms of government intervention, seeing them as a form of creeping communism. But their method was not simply to say that this was problematic because it was putting us on the road to socialism. Their method was to challenge the scientific evidence that demonstrated the need for the interventions. To challenge the evidence that demonstrated the cost, the true costs of those things, and in some cases they even launched attacks, personal attacks on the scientists who had done the work. Now that began in the late 1980s and early 1990s and you might say "well, how could three men in one think tank have such a big impact on American public opinion?" And if you asked that question you would be right, but the answer is, because over time those arguments spread, not just from the Marshall Institute but from a whole network of think tanks and organizations and lobbying groups who also began to spread this message of doubt about climate science, the same way they had spread a message of doubt about the harms of tobacco, the dangers of acid rain, the threat of ozone depletion. They began to say "We don't really know, we're not really sure, oh yes, maybe there's warming but we don't know what's really causing it," and of course, some of these claims seemed plausible and were, for many people, persuasive. This is just a partial list of the number of think tanks in the United States and elsewhere today that spread doubt-mongering, what we call doubt-mongering, about the scientific evidence of climate change. The important thing to understand about these think tanks and organizations is that they are not scientific research organizations. They don't do scientific research, they don't fund scientific research, none of them are scientific laboratories, universities, or research organizations. All of them are politically-oriented think tanks and all of them share this concern about government intervention in the marketplace. Now it's important to be clear here about what our argument is. It's perfectly legitimate to have a conversation about policy issues; in fact, in a democracy, it's essential to have open and free conversations about policy issues. So it's perfectly legitimate to argue about whether it's better to ban tobacco smoking or tax it. But what it's not legitimate to do is to fabricate evidence, to misrepresent scientific evidence, or to make what appear to be scientific claims but without scientific evidence, and yet this is what we show in our book these groups have done for the past 20 years.

12. Denial of science because of implications (24:36)

It's what my colleague Erik Conway and I call implicatory denial. That is to say, the denial of climate science is because people don't like its implications. The rejection of climate science, just like the rejection of the science related to acid rain and ozone depletion and the harms of tobacco, was not about the science. It was not motivated by a weakness in the scientific evidence. It was motivated by concerns about the implications of that evidence, because the scientific evidence had two implications that went way beyond science. One of those implications was that the free-market system, that free-market capitalism had produced serious social problems, serious costs that the invisible hand of the marketplace was not solving. And again, as Professor Schrag mentioned when he talked about energy efficiency, it also implies that we may need to change the way we live, that the American way of life may need some adjustment. You've all heard about the Catholic Church, the trial of Galileo and the rejection of Galilean astronomy by the Catholic Church in the early modern period. The Catholic Church did not reject Galileo because they were having a vigorous open scientific debate with him about planetary orbits. They rejected Galileo's work because they did not like its implications, not because his science wasn't right or wasn't supported by ample evidence, but because the implications, because it implied, that the Catholic Church wasn't infallible. So let's stop there and take questions and then in the second half of the lecture I'll talk a little bit more about how we in fact judge the scientific evidence.

13. Q&A: Should scientists create public policy? (26:21)

So let's take questions here. Yes.

[STUDENT:] What's the scientist's responsibility then to create policies?

[DR. ORESKES:] Ah, well, that's a really great question. My view is it's not a scientist's responsibility to create policies. My view is that a scientist's responsibility to do science and to communicate it as best as they can, and then it's the job of politicians, people in positions of government and authority, and other forms of community leaders, to really think about what the policy responses should be. But those policy responses, as much as possible, should be based on a robust understanding of what the evidence tells us about what's happening in the world. But I think what the responsibility of scientists is, is that if a scientist does work that has social implications, then I do think the scientist has a responsibility to communicate that. So if we'd, say, go back to the period when people were first studying the harms of tobacco, if you were an epidemiologist or an oncologist, and you found data that showed that smoking was really harmful, and back in the 1950s, between 70 and 80% of the American people smoked, it seems to me at that point you have a moral and social obligation to say "Wow," you know, "70 to 80% of the American people have a habit that is deadly and that is going to quite likely take 10 to 20 years off their lives and hurt their families and their children." And so I think there's a social obligation for scientists to communicate that and to communicate it effectively, and I think a lot of scientists would say that there is some obligation to communicate up to some point. Well, actually, I take that back. I know a lot of scientists who will say that they don't have that obligation. They'll say it's just my job to do the science. I think if you do the science but you don't communicate it when it has social implications, then it's like that proverbial tree that falls in the forest where nobody hears. You've done all this good work but what is the value and the use of that work if people don't know it exists. So I think the communication piece is very important, but when it comes to the policy responses then I think other people need to step up to the plate and get involved. Yeah.

14. Q&A: How is science communicated effectively to the public? (28:24)

[STUDENT:] You were talking about communicating to the people. Who would be communicated to and how would that be done in an effective manner?

[DR. ORESKES:] That's a really big question. Of course, that implicates what I said at the start of the talk about, it's not enough simply to throw information at people, right? And so there are a lot of people who study the question of science communication and what's effective, what works and what doesn't work, including some people in this room, and certainly people who work in museums, aquaria, people who are involved in informal science education know a lot about what tends to be effective and what isn't. So I do think the scientific community can benefit from working with people who are professionals in informal science education because, you know, as you've heard, climate change is a very complicated question. There are many aspects of the climate system that are still not well understood, but if you step back from that and you say "What does science...What does society need to know about this?" What are the key facts, the key things that we think are well understood: well, those are actually not that difficult to communicate. And so I, when I work with scientists I argue, when you're among yourselves you want to talk about what you don't know because you want to talk about the cutting edge, the research frontier, the exciting new stuff and that's great when you're with your friends. But when you talk to the public you need to step back from the cutting edge, the research frontier and talk about the things that you're pretty sure we know pretty well because that's where the policy needs to be built. We shouldn't be making policy based on, you know, things that are still kind of speculative and uncertain, but we can make policy based on the things we think we know pretty well. So we know tobacco kills people and so therefore we know it's reasonable to take steps to control tobacco use. And I think we can pretty much say that same about climate change.

15. How can the certainty of science be judged? (30:06)

So, climate change is a really big problem. You saw some of the evidence already about some of the kinds of implications, the fear of very substantial sea level rise that could drown major cities around the world, cost trillions of dollars in damage to infrastructure...effects on agriculture, drought, heat waves, wildfires, these are really big problems. These are things that will kill people, like tobacco. Arguably in some cases already have killed people. It's going to require big decisions, big investments, so I would argue that it is fair, it is appropriate for us to turn a critical eye to the science to try to make sure that we are confident that the science is robust and to do the best we can to the extent that is possible, to try to make sure that we're not wrong. So how do we do this? If you're a citizen, or a historian or philosopher of science, and you wanted to say "Well, look at the story we heard in the first lecture about how scientists changed their minds about continental drift, how do we know scientists won't change their mind about climate change?" How can we judge these claims to know whether or not they're robust? So philosophers of science have spent a lot of time thinking about these kinds of questions and they've argued that there are in fact criteria by which we, we citizens, can judge science. And those criteria fall into four main categories. What we could call methodological standards, evidential standards, performance standards, and the question of consensus. So I'm going to talk now about each of these and explain what we mean by that.

16. Climate change science is based on reliable methods (31:40)

So let's start with methodological standards. I talk in my first lecture about the different scientific methods and the fact that there had been arguments in the 20th century about which methods were preferable. But one thing that almost everybody agrees on, whether you prefer induction, deduction, or some hybrid between, is that valid science is accomplished by using reliable methods. That is to say, by using methods that have stood the test of time. And the simple, most basic scientific method that goes back to Newton and beyond is observation. To make observations about the natural world and simply to report on what we see. And so in the case of climate science, one of the simplest basic observations we can make, which you've seen already, is that the temperature of the Earth has increased since the Industrial Revolution. That if we take temperature records from around the globe going back to the 1880s, which is the earliest period for which we have systematic and reliable records, we see that the temperature has risen. As Professor Schrag said, not exactly in a linear manner, there are ups and downs, some of those ups and downs may have been caused by other forms of pollution like coal dust, but overall the temperature has risen. That's a basic observation. Moreover in science we'd like to say, we generally do say, one observation is good, a hundred is better, a thousand is better than that, and it's especially good to have a lot of observations if some of them are completely independent, what scientists would call independent corroboration. So we really like it when, if one group of scientists makes a set of observations, and comes to conclusion X, if a different group of scientists, completely independently, working in a different place, maybe using different instruments or different techniques, replicates that set of observations, and they also come to conclusion X, well, then we feel more secure. And if we do it three times or four times or five times, then we say that we have robust independent corroboration. So this is a graph showing a series of several different independent temperature records from different scientific groups using different techniques, different proxy records, and in this case reconstructing the temperature record not just to 1880 but going back to the year 600. And what we see is that, although the records are somewhat different, you can see the records are extremely noisy, there's a lot of ups and downs, and they don't all agree in all details, but nevertheless, the one thing that they do all agree on, if you look at the right-hand side, which is what has happened to global temperatures since the industrial revolution-- they all show a rapid, dramatic rise in mean global temperature. So we have observations and we have independent corroboration of those observations. So that's essentially the inductive method that I talked about,

17. Climate science and the deductive method (34:28)

but what if we like deductive science better? What if we think it's better to start with a theory, make predictions and then see if the predictions come true? Well, the fact is that climate scientists have done that too. In fact, this science goes back more than a hundred years, when Svante Arrhenius, a Swedish geochemist, predicted in 1896, he argued that we know that carbon dioxide is a greenhouse gas, we know that when you burn coal it produces carbon dioxide as a byproduct, therefore we predict that climate change will happen. Now, Arrhenius was Swedish so he thought global warming would be a good thing. Now we realize it's a bit more complicated than that but if we look at Arrhenius's prediction and we look at the data that we have now, a hundred years later, we find that that prediction has come true. So on the left here's the carbon dioxide rising, on the right, indeed, temperatures have risen as predicted by basic physical theory. Now many of you if you've taken any statistics or maybe you've talked about this in science classes, you know that just because two things happen together doesn't mean that they're causally related. You know that two things can be correlated, and a correlation is not the same as a causation or a causal effect. But this connection is not just a correlation. This is the confirmation of a prediction that has come true.

18. Science is falsifiable (35:49)

Now some scientists have thought about his problem in an entirely different way. They've argued "We're not trying to show that our theories are right, what we're trying to do in science is to show that our theories are not wrong." That's partly why I titled my lecture "How Do We Know We're Not Wrong," not "How Do We Know We're Right." And one of the most famous philosophers who promoted this view was the philosopher Karl Popper who argued that, if we really want to claim that something is scientific, then what we need to be able to show is that there's some observation or some test that we could make that, if we did that test, we might be able to show that the theory was wrong, we could be able to show that the theory was false. In other words that the theory is what he called falsifiable. There's some test we could do that would tell us if we're off base.

19. The claim that volcanoes cause rising CO2 is false (36:39)

So can we do that with climate science? Well, yes. Let's consider this question about the source of carbon dioxide. So we know carbon dioxide levels are rising, even the climate contrarians, skeptics, and deniers do not deny that carbon dioxide has risen. Everyone agrees with that, even the most die-hard contrarians. But you could argue, and indeed some of them do argue, that the carbon dioxide is not coming from burning fossil fuels and changes in land use, that that carbon dioxide is coming from volcanoes. Well you heard something already today about carbon dioxide and in fact, we know that that's not true because, as Dan Schrag told you, the amount of CO2 coming from volcanoes is actually very, very tiny. But let's set aside that argument. Let's say we didn't know how much carbon dioxide was coming from volcanoes. Is there something we can do to test that hypothesis that would tell us if that hypothesis were false. And the answer is yes. And it relies on the isotopes that you heard about from Professor Knoll. Volcanoes do emit carbon dioxide, but it has a different carbon isotope signature than carbon dioxide that you get when you burn fossil fuels. So you heard yesterday about how organic molecules tend to be depleted in the isotope carbon-13. Organic life tends to prefer light carbon, carbon-12, so when organic molecules are forming, they preferentially absorb carbon-12 out of the atmosphere and tend to leave carbon-13 behind. So when you have biomass that becomes fossil fuels, those fossil fuels are depleted in carbon-13. So if you burn those fossil fuels, you should be returning carbon dioxide to the atmosphere that is low in carbon-13, depleted in carbon-13. So we have a test of the theory, a test that could enable us to falsify the volcanic theory. If the carbon in the atmosphere that Dave Keeling measured was mostly coming from volcanoes, the ratio of carbon-13 to carbon-12 in the atmosphere should not change. But if it were coming from fossil fuels then the ratio should change, it should decline. So scientists have done that test. They have measured the carbon isotopic composition of the CO2 in the atmosphere and here's the result. This is a really beautiful graph. This is one of my favorite graphs of all the things I ever talk about. So here's...on the right, there's carbon dioxide increasing since the Industrial Revolution, from an original level of about 280 parts per million to pushing, well, only 350 by the year 2000 but pushing 400 now, and here's the carbon isotopic signature. You can see that the carbon-13 value is falling and it's practically a mirror image, so as the CO2 rises, the carbon-13 falls, and that tells us that the volcanic hypothesis is false. So if anybody tells you that the carbon dioxide in the atmosphere is coming from volcanoes, it's like I said in the video they're either confused, ignorant, or lying.

20. The process of peer review and the IPCC (39:44)

Now, here's the criteria that I like the best as a historian and sociologist, because at the end of the day, we don't have any way to prove that scientific theories are correct. We simply don't. We might like to but we don't. But one thing we can ask, one thing that's actually relatively easy for someone like me, as a historian and with some training in sociology of science as well, we can ask the simple question, have these claims passed peer review? That is to say, have they been judged by fellow scientists, have they been subjected to critical scrutiny by other experts in the field who understand the question, and have those other experts said "Yes, these are good data, this is robust evidence, this claim makes sense." And that process of critical scrutiny is what we call peer review. So let's talk a little bit about how peer review works. In science when researchers make claims they don't just tell their students, they write a paper, and they attempt to publish it in a peer-reviewed scientific journal. So we could imagine a claim, this is a ridiculous claim, I didn't come up with this-- imagine that toasters in space are heating the Earth. Okay, we know that's sort of silly, but let's just say for the sake of argument, some scientist or some would-be scientist made that claim. So, the scientist, or the person, the researcher, writes a paper and submits it to a journal. The editor of the journal then sends that paper to experts in the field. People who have expertise in this subject and understand it very well, typically two or three different people, and hopefully people who are not friends of the person who wrote the paper. So those experts scrutinize the paper. They ask themselves the question: is there sufficient evidence in this paper to support the claim? Is the evidence sufficiently well documented? Is it sufficiently well explained? Is it consistent? If the answers to those questions are "yes," it doesn't prove that the claim is correct, but it proves that the claim is at least reasonable for now, and the paper will likely be accepted for publication, and it goes into the body of peer-reviewed literature. But if the answer to one or more of those questions is "no," then the paper will be rejected. So in the case of the hypothesis of toasters in space, it would be rejected because there is no evidence to support the claim that the Earth is being heated by toasters in space. And indeed, one of the things that I found in my research is that, although many people have heard the claim that climate change is being driven by volcanoes, if you look in the peer-reviewed literature, you cannot find articles supporting that claim because in fact, the evidence doesn't support it. So many of these contrarian claims are not actually scientific claims. They're claims that come, as I've already said, from these non-scientific think tanks. Now in the case of climate change, though, we actually have an additional level of peer review and that's the organization called the IPCC, the Intergovernmental Panel on Climate Change. This is an organization consisting of thousands of scientists around the globe from 195 countries who, in their reports, subject the peer-reviewed scientific literature to what is in a sense a second round of peer review. It's a highly open process. It involves, as I've already said, thousands of scientists, and also people in the public and in NGOs and in environmental groups, and governments comment on the claims as well. As a historian of science, I would say that the IPCC represents a level of peer review and inclusivity that is unprecedented in the history of science. So the claims of climate scientists have been actually subjected to more scrutiny and more review than, say, any of the claims associated with plate tectonics.

21. How well do climate models perform? (43:30)

The final idea is a kind-of-complicated and subtle one, and it's the idea of performance. It's the idea that if our knowledge is correct it ought to be able to stand up in action. So I might say that I don't believe in gravity, and because I don't believe in gravity I'm going to jump out of a tenth story window. But that knowledge is not going to hold up very well in action when I hit the ground and fracture all of my bones, at best. So we can judge knowledge a little bit by how well it works when we're trying to do things with it. So in the case of climate science a lot of the judgments about the performance of climate science are tied up with climate models. And climate models are extremely complex, many of them involve millions of lines of computer code-- very difficult, if not impossible for any one person to really understand a climate model. So we can judge the model by its performance. Is it consistent with what we actually see in the real world? Well, the IPCC did a very interesting test of the performance of climate models. They compiled observations that people were making about changes that were going on in the natural world. So those changes could involve things like the shrinking of the Arctic sea ice, but they could also involve things like changes in the distribution of butterflies, changes in when flowers were blooming in the springtime, changes when maple syrup was running in New England-- a whole variety of different kinds of things. And they compiled 28,671 significant observed biological changes around the globe. So these are things that people have actually seen. And they asked themselves the question, what percentage of these changes are consistent with warming as predicted by the climate models? And the answer was 90%. That's a pretty good track record. If you tried to predict, you know, stock prices, you wouldn't come anywhere close to predicting them 90%.

22. Climate extremes in North America: September 2012 (45:27)

Climate scientists have also been warning for some time about the intensification of extreme weather events. And as Professor Schrag said, again, basic physics: a warmer atmosphere can carry more moisture, there's more energy in a warmer atmosphere. That moisture, that energy, has to go someplace, and one of the places it can go is into extreme weather events. So if we just take one month, last September, September 2012, many different extreme events were happening just in the United States alone, so not including the rest of the world. Wildfires burned over 1 million acres nationally. California and Nevada, Utah, and Wyoming all experienced warm Septembers that were in the top ten warmest Septembers ever recorded. There was record dryness in Montana, Minnesota, North Dakota, and South Dakota. Sixty-four percent of the country was in drought. Hurricane Isaac spawned tornadoes way outside of Tornado Alley, in Alabama and Louisiana. We don't normally think of tornadoes as being in Alabama. The Ohio valley, on the other hand, was wetter than average. There were severe thunderstorms and tornadoes in New York City. And of course, as you all now know, super storm Sandy, whose impacts we don't need to belabor.

23. Scientific consensus exists for anthropogenic climate change (46:42)

And finally then, the idea of consensus. In my own work I've been interested for a long time in the question of scientific consensus: how scientists achieve it, how we would know it if we saw it, and how to think about what it means. So a few years back I did a review of the scientific literature, simply asking the question, if we look at the published peer-reviewed literature, how many of the papers in the peer-reviewed literature disagree with the claims that had been put in the IPCC reports, or the National Academy of Science's reports on this issue? What my students and I found was that 75% of the papers explicitly endorsed that position-- that anthropogenic climate change was underway and mostly caused by human activities. And the other 25% were actually about other things: mostly about paleoclimates--so, explaining stuff about paleoclimate variability-- or they were on instrumentation, technical aspects and essentially... or didn't take a position one way or the other. Of the papers that actually addressed the question of anthropogenic climate change, not one, not one of nearly a thousand papers published in peer-reviewed journals refuted the claim that climate change is happening and mostly caused by human activities, mostly caused by the increasing greenhouse gas concentrations over the last 50 years. So there is a consensus among scientists. There is a consensus about climate change.

24. The science is settled: Time to focus on what we should do (48:10)

The science is settled and it passes all of the tests that we can subject it to. The globe is warming, the climate is changing, it's because of the things that we do, and our debate should not be about whether or not climate change is happening, it should be about what we're going to do about it. Now we can take some questions.

25. Q&A: Is regulation up to the government or us? (48:41)

[DR. ORESKES:]Yeah, right here.

[STUDENT:]Do you think the government is going to regulate issues for climate or is it going to be up to us?

[DR. ORESKES:] Ah, well, those of course are related because what the government does is going to be up to us, because I think that, history shows that very often leaders don't lead, they follow. Public opinion is incredibly important, it's probably more important now because we have all this immediate polling and stuff. So I think it is fundamentally up to us, in the sense that our government will respond to what we demand.
So I do think it's up to us to make our government act, but I think you didn't quite mean it that way, you meant, like, personal actions versus government regulation. Is that, I assume? I think again, it's a bit like what Professor Schrag said about mitigation or adaptation; it's got to be both. I think it's got to be both in this case too. There's a lot that you can do as an individual. Energy efficiency, a lot of energy efficiency can take place in individual households. You all make decisions every day and the decisions you make make a difference and there's some very persuasive studies...Amory Lovins is probably the most persuasive expert on this. He has a great new book called Reinventing Fire. He argues that we could cut our energy usage between 30 and 50% just through our own decisions. So I do think there's a lot that people can do by themselves, yet at the same time there are also some things individuals can't do. So I can change my light bulbs but I can't change my electricity grid. Right? I can change my light bulbs but I can't personally change the fuel that my utility is using. And that's where government comes in. So where I live in California we now have AB32, which is a law that requires the state of

California to reduce greenhouse gas emission, and part of that law is what's known as renewable portfolio standards. We're seeing businesses in California begin to adopt alternative energy. My own university put solar panels on the roofs of our parking lots, and part of this is being driven by the law. It's being driven by the renewable portfolio standard. So, you know, there's the old saying, "Necessity is the mother of invention," and Erik Conway and I argue, one of the most powerful forms of necessity is government regulation. So I think that government regulation can do a lot. Government regulation is how we solved acid rain and the ozone hole, so I think it's going to be an essential component of this story as well. I don't think it can be done just by individuals alone.

26. Q&A: Which is correct, "global climate change" or "global warming"? (51:04)

Yeah.

[STUDENT:] Is it your opinion that you prefer the term climate change, global warming, or something else and why?

[DR. ORESKES:] Okay. That's a great question and so it's actually a very complicated question and in our book we talk about this. So if you go back to work that scientists and policy makers were making about this issue in the 70s and 80s you see both terms being used. But in the early 1990s, a consultant to the Republican Party advocated that Republicans shouldn't use the term "global warming," they should use the term "climate change" because, he argued, "climate change" was less frightening. And so if you didn't want people to be worried about climate change, you should talk about climate change and not global warming. Now a lot of...I get asked this question a lot, and knowing that there have been conscious deliberate efforts to manipulate our language on the issue, you know, there's a part of me that says, if someone is telling me not to talk about global warming, and I should talk about climate change, of course, I'm slightly contrarian too, so then that makes me want to talk about global warming. On the other hand, a lot of my scientist friends would say that actually climate change is a more accurate term, because we're not just talking about warming, and a lot of the most worrisome consequences aren't necessarily the warming itself, but all of the changes that follow on from the warming. So I do think that climate change is actually a better term to use to really encompass what we're talking about. So even if it was advocated by some people for reasons that I might not personally agree with, I still think it is actually a better term.

27. Q&A: How should data be made more accessible? (52:40)

Yeah.

[STUDENT:] How do you think we should make this data more accessible and more comprehensible for the general public who doesn't agree with the climate change consensus?

[DR. ORESKES:] Right. Well, I think there's two things. So, just as I said in my first lecture that no consensus is ever 100% and there will always be some scientists who have different opinions and that's fine. That's true in politics as well. So I don't think that it's necessary to persuade every person in the United States of America that climate change is happening. Public opinion polls show that about 20 to 25% of the American people still don't believe that smoking cigarettes causes cancer. Well, oh well, you know? There's a point at which there might not be anything you can do about those people, and if they want to smoke, it is a free country, as long as they don't do it in my face, right? So I think that it's really important when you think about communication, not to worry about lost causes. Right? And from a political standpoint you don't need 100%, but you do need a majority, and you need a robust majority of people who are involved in the political process. So I think it's really important to think about what I would call "the confused middle." Tony Leiserowitz at Yale has done some very nice work on this. There are a lot of people in the middle-- and I meet these people all the time on airplanes, and sometimes they come to my talks-- who are not deniers, they're not working for the Cato Institute, but they are confused, or they don't know what to think, or maybe they think climate change is real, but they feel it's not going to happen for another 500 years, it's not my problem, it's China's problem. I mean there are a lot of different ways people can rationalize doing nothing, and we know there's lots and lots of evidence that people have a status quo bias. If they have a choice between continuing doing what they're doing or changing it, there's some people who like change, but most people don't, most people will continue. So I think that the important thing now is to focus on that confused middle to explain to them, as someone asked earlier, simple explanation for how we know this is right, focusing on the main points, simple explanation on why it really matters, and especially focusing, I think, from my experience talking to people... now. Lots and lots of people think this is a problem in the future. I have to say I think a lot of scientists have contributed to that, because a lot of times when scientists talk about climate change, they do talk about the long-term predictions, and some of that is because, as Professor Schrag said, we can be really confident about some of the long-terms predictions. We're a little less confident about the short run, and so scientists don't like to talk about things they're not confident about, so it's safer to talk about the long run, but the reality is that climate change is happening now. It's affecting people now, and I think as people begin to understand-- as I think in New York City they now do, the mayor clearly does--as people begin to see it as a present-tense problem I think that will shift people's sense of urgency about the issue.

28. Q&A: How do we consider the economic costs of regulation? (55:29)

Yeah?

[STUDENT:] How much should our lawmakers weigh the economic affects when increasing regulation?

[DR. ORESKES:] Right, great question. So the economic effects are obviously extremely important but they cut both ways. Some people who have resisted the idea of a carbon tax or a cap-and-trade system or any effort to address the issue of energy efficiency, raise this issue of the cost, that it's going to cost a lot of money. And they're certainly right that it would be silly to spend billions of dollars on a problem that wasn't serious, but we know that the problem is really serious. We also know that the problem itself is going to have a lot of costs and I think...I actually think one of the good things that hurricane, superstorm Sandy did-- it's hard to talk about the good aspects of a disaster, right?--but I think a lot of people have been actually very naïve about the cost of climate change. So we hear about the cost of regulation in part because people who don't like regulation make a big point about talking about the cost of regulation, but the reality is that there are extremely large costs about not doing something about climate change. So now we look at the damage in New York, in the New York metropolitan area, and people are talking about...I don't know what the latest figures are, between 30 and $60 billion in damage to infrastructure. That's a huge cost. And so the economists who have been looking at this question have a very persuasive argument that the cost of climate change is actually probably greater than the cost of remedying it. Now of course, it depends on what the remedy is. Some remedies are more expensive in dollars and cents than others, and of course it also depends on how you think about costs. So, to me, living in California where we have renewable portfolio standards, I don't really see that as a big cost. It's not hurting my life, you know? But you're absolutely right that we need to think about it, but the crucial point is, if Manhattan ends up under water, if lower Manhattan ends up underwater, that's a pretty big cost. Right? So, thank you very much. It's been a pleasure being here again.