VOLUME 13-A

UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF VERMONT

GREEN MOUNTAIN CHRYSLER-PLYMOUTH-DODGE, et al.	*	
THE ASSOCIATION OF INTERNATIONAL AUTOMOBILE MANUFACTURERS	*	
V	*	
GEORGE CROMBIE, Secretary of Vermont Agency of Natural Resources, et al.	*	Civil File No. 05-302 & 304

TRIAL BY COURT
Thursday, May 3, 2007
Burlington, Vermont

WITNESSES:
K.G. Duleep
James Hansen

BEFORE:

THE HONORABLE WILLIAM K. SESSIONS III
Chief District Judge

ANNE E. NICHOLS
Registered Professional Reporter
United States District Court
Post Office Box 5633
Burlington, Vermont 05402
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Continued.....

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I N D E X

E X A M I N A T I O N

E X H I B I T S

*admitted provisionally.

evidence.)

(Witness excused.)

THE COURT: Are we ready to proceed with the next witness?

Okay, Mr. Pawa.

MR. PAWA: Your Honor, we would ask for a two-minute recess to set up a computer.

THE COURT: That's fine.

(Court was in recess at 11:39 a.m.)

(The following was held in open court at 11:50 a.m.)

THE COURT: All right, Mr. Pawa?

MR. PAWA: Matt Pawa. May it please the Court. Plaintiff -- defendants call Dr. Hansen as an expert witness.

JAMES HANSEN,

having been duly sworn by the courtroom deputy, was examined and testified as follows:

THE COURT: Good morning, Dr. Hansen.

THE WITNESS: Good morning.

DIRECT EXAMINATION

BY MR. PAWA:

Q Dr. Hansen, please state your name, your full name and address for the record.

A James Edward Hansen, 4273 Durham Road, Kintnersville, Pennsylvania.

Q What is your current occupation, Doctor?
A I am a physicist and director of the NASA Goddard Institute for Space Studies.
Q Could you tell the Court a little bit about yourself, where you are from, where you grew up, whether or not you have any children, grandchildren.
A Sure. I am -- I was born and grew up in Iowa. I was born on a farm. I -- most of my life I grew up in a small town in western Iowa.

I was fortunate to grow up at a time and place where I could go to school, I could work my way through school, and the most fortunate think, I think, was I went to a school, University of Iowa, where the head of the physics department was Professor James Van Allen, the scientist who discovered the radiation belts around the Earth. And he created -- he was both a great scientist and a great person, but he had a wonderful science department, physics and astronomy.

I started out in astronomy actually, but I -- it was a great research environment, and that's where I got started in science.
Q And do you have any children or grandchildren, Dr. Hansen?
A I have two children; two grandchildren, a third one in a few months.

Q Thank you. Are you prepared today to give the Court an opinion in this case with respect to the risks of -- to the climate of continuing with business-as-usual emissions of greenhouse gases from motor vehicles and other sources?

A Yes, I am.

Q Are you also prepared today to give the Court an opinion, in your scientific judgment, with respect to the most significant risks related to abrupt climate change?

A Yes, I am.

Q And, Dr. Hansen, are you also prepared today to give the Court an opinion, in your expert scientific judgment, in this case, with -- regarding the role of the emissions reductions here as part of a wider set of emissions reductions in order to stabilize the planet's climate and reduce the risks of abrupt climate change?

A Yes, I am.

Q Before we discuss the contents of those opinions, Dr. Hansen, and how you came to them in this case, could you tell us in greater detail, please, what your educational background and experiences are and any awards you may have received in the course of your career.

A Yes. Well, I graduated from high school in 1959.

And I went to the University of Iowa. I got my Bachelor's degree in mathematics and physics, and when I was a senior, I was the first student who took the graduate qualifying exams as an undergraduate, and was the first student to pass; I mean of those exams. So I went then to the graduate school at the department of physics and astronomy.

I got my Master's degree in astronomy on observations of eclipse on the moon and interpretations of that in terms of what it meant about the Earth's atmosphere.

And at the suggestion of Professor Van Allen, I investigated -- I studied the atmosphere Venus, new observations that had been taken of the atmosphere of Venus, and for the purpose of trying to understand why Venus was so hot. And I wrote my Ph.D. thesis on that topic.

And I, immediately after getting my Ph.D., I drove to New York City, because I had applied for and received a post-doctoral fellowship at the NASA Goddard Institute for Space Studies, and I have been there at Columbia University ever since then.

The first 10 years of my career were spent on other planetary atmospheres. I proposed an experiment to investigate the clouds of Venus, and that experiment was

selected for the mission Pioneer Venus. It was a small telescope to measure the cloud particles and the cloud -- cloud and aerosol properties on Venus.

And during the time -- so I was the principal investigator on that experiment.

But during the time that that was being constructed in California, I became interested in the Earth's atmosphere because of the evidence that the composition of the Earth's atmosphere was changing, and it made it both a very interesting planet and also one that's obviously important for people, for life on this planet. And I began to do work on, and I applied for support, to develop a global model to try to simulate the Earth's climate and the effects that these changes in the atmospheric composition would have on the Earth's climate.

And I did receive support for that, and it was a very time-consuming job. So I actually resigned as the principal investigator on the Venus experiment and one of my colleagues assumed that job.

But since that time, the late 1970s until the present, I have been focusing essentially a hundred percent of my time on trying to understand the Earth's climate.

Q And for how long have you held the position that

you hold now?
A I became the director in 1981, when Dr. Jastro, who founded the institute, retired. And I have been the director since then.
Q Are you a member of any professional societies, Dr. Hansen?
A Yes. I am a member of American Geophysical Union, American Meteorological Society, and I am a member of the National Academy of Sciences.
THE COURT: Can I just interrupt for a second.
MR. PAWA: Please.
THE COURT: When someone mentions Goddard Space Center or Goddard Space Research Institute, is there just one particular unit or are they all over the place?
THE WITNESS: Well, Goddard Space Flight Center is a large organization. It's near Washington; Greenbelt, Maryland. That's several thousand people. The institute, in New York, is only 22 civil servants, government employees, and about 120 people, counting the students, post-docs, and other employees. So it's -- and it is a division of Goddard Space Flight Center.
But it was founded -- Dr. Jastro, when he was asked to head the theoretical division at Goddard Space Flight Center, accepted the job but then immediately asked to

move it to New York City where he could be in an academic environment on the campus of Columbia University. And it was a -- for doing research, it was a great environment, and --

THE COURT: Well, I was going to ask you to express my regard to Queen Elizabeth who soon will be going to Goddard Space Center.

THE WITNESS: Oh.

THE COURT: But apparently that's in Washington, not where you are.

THE WITNESS: In Washington. Right.

BY MR. PAWA:

Q Which brings me to an important point. Are you today --

THE COURT: We should go another 15 minutes before the lunchbreak, in light of the fact you are just beginning the introduction.

MR. PAWA: What I was going to suggest, we can do that or I can finish the qualifications portion and then break before we get into substance, if that's acceptable.

THE COURT: That's fine.

MR. PAWA: Thank you, your Honor.

By MR. PAWA:

Q Are you here today as a private citizen or a

government employee, Dr. Hansen?
A I am here as a private citizen.
Q Throughout your involvement in this case, has it been as a private citizen?
A Yes.
Q Have you won any awards during the course of your scientific career, Dr. Hansen?
A Yes, I have won a few. And I mentioned them to you yesterday. And that reminded me that one of them I had forgotten to mention was from Prince Philip, the Duke --
THE COURT: You won an award from Prince Philip?
THE WITNESS: Well, from the World Wildlife Fund. The conservation medal for -- it's called the Duke of Edinburgh Award, and it's presented by Prince Philip. And my wife and I went over and had lunch with him. But, that was one of the awards.
Probably the most significant award is being elected to the National Academy of Sciences.
Well, I just -- a couple of weeks ago was given the Leo Szilard Lectureship Award at the American Physical Society meeting. That's the organization of physics professionals in the United States. And that's considered a major award of that organization.
Q Have you ever won an award from the American

Geophysical Union?

A Oh, yes. The Roger Ravel Medal, which is a major award from AGU. There's the Heinz Environment Award I won several years ago.

Q Any recognitions from GIS with respect to publications?

A Oh, well, at our institute, we -- we've -- all the scientists vote on the best publication of the year, and I have won that a few times. We consider that our highest award because that's our business, to do research.

Q Is the atmosphere of Venus, your work on the atmosphere of Venus, relevant in any respect to your work on the climate of planet Earth?

A Yes. The planets actually provide a very nice test of our understanding of the greenhouse effect, because we have planets that range from Mars, which has a thin carbon dioxide atmosphere, to Venus, which has a much thicker, larger amount of carbon dioxide, and with the Earth in between those two examples. And when we use the basic equations of radiative transfer to calculate the expected temperature of these three planets, they fall nicely along the curve for the change of the -- the strength of the greenhouse effect as a function of the amount of the greenhouse gas.

Q Have you published any articles regarding global warming or climatology generally in the peer-reviewed literature over the last 30 years?
A Oh, sure. More than a hundred articles in the peer-reviewed literature on that -- on that general topic.
Q Are there any other academic peer-reviewed publications that you have been the author of?
A Other than --
Q Book chapters or --
A Oh. Yes. I have edited a book myself on the climate change and paleoclimate, but -- but most of my articles are in the scientific, regular scientific literature, reviewed literature.
Q Thank you.
MR. PAWA: Your Honor, we move to qualify Dr. Hansen as an expert in climatology.
THE COURT: Okay, any objection?
MR. CLUBOK: No objection, your Honor.
THE COURT: So qualified.
All right, you want to take a break at this point?
MR. PAWA: Yes, your Honor. Thank you.
THE COURT: All right let's take our break, and -- well, first of all, is Dr. Hansen the only witness to be called this afternoon?

MR. PAWA: Well, it kind of depends, but I think we may be getting to Dr. Rock this afternoon as well. As of this morning, we were thinking Dr. Rock would come on tomorrow because Duleep wouldn't get off till lunchtime, but we are moving a little faster now so I think we may get to Dr. Rock today.

THE COURT: How long do you think direct examination will last?

MR. PAWA: For this witness?

THE COURT: Yes.

MR. PAWA: 90 minutes.

THE COURT: And cross examination, Mr. Clubok?

MR. CLUBOK: Less than 30.

THE COURT: Okay. Well, then let's come back at 1:15 and go for an hour and a half, and then another hour and a half, and try to make up for the lost time from yesterday afternoon.

MR. PAWA: Thank you, your Honor.

THE COURT: All right. Thank you.

(Court was in recess at 12:05 p.m.)

*** ** ***

C E R T I F I C A T I O N

I certify that the foregoing is a correct transcript from the record of proceedings in the above-entitled matter.

_____ _____
Date Anne E. Nichols

VOLUME 13-B

UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF VERMONT

GREEN MOUNTAIN CHRYSLER- PLYMOUTH-DODGE, et al.	*	
THE ASSOCIATION OF INTERNATIONAL AUTOMOBILE MANUFACTURERS	*	
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GEORGE CROMBIE, Secretary of Vermont Agency of Natural Resources, et al.	*	Civil File No. 05-302 & 304

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Thursday, May 3, 2007
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WITNESSES:
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Chief District Judge

COURT REPORTER: JOHANNA MASSE, RMR, CRR

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EXAMINATION

EXHIBITS

THURSDAY, MAY 3, 2007

(The following was held in open court at 1:18 p.m.)

THE COURT: Okay. Dr. Hansen, do you want to return to the stand? I hope you enjoy Vermont weather.

THE WITNESS: Yes. Great.

THE COURT: Okay.

DIRECT EXAMINATION - CONTINUED

BY MR. PAWA:

Q Dr. Hansen, you were asked to prepare an opinion in this case regarding recent global warming.

A Yes.

Q And have you prepared such an opinion?

A Yes, I have.

Q Have you prepared a series of slides and charts to help assist you with your testimony in that regard today?

A Yes, I have.

Q Have you prepared a series of slides and charts dealing with observed temperature change in the modern era?

A Yes.

MR. PAWA: I would ask for Slide 1 to be shown to the Court.

Q Dr. Hansen, can you explain what this chart shows with respect to the issue of global warming.

A Yes. This shows the global surface temperature beginning in 1880. The X-axis runs from 1880 to the

present, and the temperature is shown in degrees Celsius as temperature change in degrees Celsius relative to the period from 1951 to 1980, which we call a period of climatology. So to get degrees Fahrenheit, you need to multiply this times approximately -- approximately double it. Multiply it times 1.8.

So what it shows is that the world -- the surface temperature, it's measurements over the ocean and the land, but surface temperature's increased by about 8/10ths of a degree Celsius with three-quarters of that warming coming in the last three decades. So about 1 degree Fahrenheit in the last three decades.

Q Can you place that into perspective for the Court in terms of how much warming that is relative to other information?

A You know, we will show that in other charts. The 1 degree -- 1 degree -- this is 8/10ths of a degree Celsius, but 1 degree Celsius is actually a very large change for global mean temperature, but -- and it will show that that has many effects. But, of course, compared to weather fluctuations, day-to-day weather fluctuations, this is much smaller, and that's sometimes a source of confusion to the public because the weather -- the temperatures will fluctuate by much more than this. Because the local temperature depends upon the direction from which the wind

is blowing. If it's coming from the north or south, it makes a difference of 10 or 20 degrees. But as we will show, this is actually a pretty big temperature change.

Q What was the global average temperature of the Earth in the depths of the last ice age, 20,000 years ago?

A It was about 5 degrees colder than it is now, and, of course, some regions it was more than that. On a global average, it was 5 degrees and --

Q Celsius?

A Celsius, which is 9 degrees Fahrenheit.

Q And what was this area of the country like 20,000 years ago --

A Well --

Q -- when it was 9 degrees Fahrenheit colder on a global average?

A During the last ice age, sea level was about 120 meters lower. There was so much water locked up in the ice sheet that covered Canada and reached down to New York City and covered Minneapolis and Seattle, including -- including this region, so it's a huge regional climate change associated with the 5-degree global temperature change.

Q Have you prepared other slides on the issue of observed temperature change in the modern era?

A Yes. And I have a number of them, so I think we should move through those so that the --

Q What does this chart show, Doctor?
A This chart shows the temperature anomalies. These are global maps of the temperature anomalies, again, relative to 1951 to 1980. Yellows and reds are warmer than normal. Warmer than the climatology from 1951 to 1980. And blues are colder than normal. So the point of this is to say that when you look at a given month, like February, for example, in the lower right, you can see that the United States was very cool. About several degrees cooler than normal. But that's associated with the weather patterns that happened to exist that month.

So you shouldn't be fooled by the temperature going up and down and being cooler than normal in some months. That's normal. But if you look at the average over the planet, you'll see that in fact there are more red and yellow areas than there are blue. And in fact, this last winter was the warmest winter in the last 125 years, in the full period of instrumental record.

So why don't we go to the next one, which shows that --
Q One moment.

MR. PAWA: I want to move to admit the first one into evidence, Your Honor.

THE COURT: Okay. Is there going to be any objection to any of the slides that he uses for demonstrative purposes, in which case you don't need to

interrupt on a regular basis? For instance, has the plaintiff reviewed all of these?

MR. CLUBOK: I had not, Your Honor. We got -- we got them at midnight. But I've told Mr. Pawa I wasn't even going to raise that objection or mention it, but I'm just seeing these for the first time in some cases, so I presume they'll be okay, but I'm as worried about them as you are.

THE COURT: Rather than interrupt, why don't you go through all those slides, all the presentations, then at the end submit them all.

MR. PAWA: Thank you, Your Honor.

THE COURT: Okay.

MR. PAWA: And I will just indicate for the record that the vast majority of these are identical to what was included as an appendix to his expert report. There are a few slides that are different.

THE COURT: Okay. All right.

BY MR. PAWA:

Q Proceed to the next slide, please.

A So this, then, shows the average temperature anomaly in the first six years of this century, 2001 to 2006, again, relative to 1951 to 1980. And you can see that when you average over time, those weather fluctuations are no longer so apparent. In fact, it has warmed over most of the planet. And the nature of this warming is -- is consistent

with what we would expect due to a forced climate change, and it's consistent with the sort of thing that's calculated with global climate models.

So, for example, you see that the warming is larger over land than it is over ocean. It's because the ocean has great thermal inertia. So when a forcing is applied -- and I'll explain what that is in a minute. But in case of forcing -- something that would cause the planet to get warmer, it takes the ocean several decades to respond. Because the ocean is four kilometers deep, it takes a long time for it to warm up in response to the forcing.

So the warming is larger over land than over ocean. It's larger in the northern hemisphere than the southern hemisphere because there's so much ocean in the southern hemisphere, and the ocean there mixes deeply. And the warming is larger at high latitudes than it is at low latitudes, because at high latitudes there are feedbacks that enhance the warming. In particular ice and snow tend to melt as the planet gets warmer, and, therefore, the land and the ocean where the ice has melted are darker, and they absorb more sunlight. That's what we call a positive feedback.

So it has all the characteristics that we expect in calculated climate models.

Q Dr. Hansen, could you explain these two concepts that

you've used, forcing and models?

A Yes. Forcing is a perturbation -- an imposed perturbation to the planet's energy balance. So, for example, if the sun were to be become 1 percent brighter, that would be a positive forcing, which you would expect the planet to warm up. And we measure that forcing in watts per meter squared. The Earth absorbs about 240 watts per meter squared of energy from the sun, so if the sun became 1 percent brighter, that's a forcing of 2.4 watts per meter squared. And -- so that's the definition of a forcing.

And a climate model is numerical calculations on computer of fundamental equations that describe the structure and motions of the atmosphere and ocean. So, for example, conservation of energy and momentum and ideal gas law. But certain fundamental equations of physics and the Earth's atmosphere solved simultaneously on a large computer.

It's the kind of model that's used for the daily weather forecasts except that in the case of climate, you have to include factors which are important on longtime scales but are not important on the time scale of a few days. So we have to include the thermal inertia of the ocean and changes that occur in the carbon cycle. By that I mean the uptake of gases by the ocean, for example. Things that change slowly on a decadal time scale need to be

included in climate models but are not necessary in weather models.

Q Does the NASA Goddard Institute for Space Studies have one of these models?

A Yes. As I mentioned during the introduction, that's something that I began to work on 30 years ago. We had -- at that time we had a weather model, and we -- my project was to convert that to a climate model by adding in the physics that's important on longtime scales. And we have one of the several models in the United States.

Q And do these models run on normal computers or some other kind of computer?

A Well, they -- they -- it's a computationally intensive problem, and so you prefer to use the best computers you can. In fact, when we started, we had -- in 1967 we had the largest computer, fastest computer in the world, an IBM 360/95. In any case, computers continue to get better and better and we can solve the climate problem more accurately with -- as the computers have been improving and as the representation of the physics in the models has improved.

Q What do the terms GCM or AOGCM stand for?

A GCM used to be for general circulation models, but now sometimes global climate model; but in any case, it's the same thing. It's these fundamental equations for atmospheric structure and motion. And AO is atmospheric-

ocean. So if you include some previous models would just be atmosphere, you just took the ocean as being fixed because you only wanted to look at a short time scale; but if you want to look at climate, you've got to include the ocean. So then it becomes atmosphere-ocean climate -- global climate model.

Q Are greenhouse gases a climate forcing agent?

A Yes. Greenhouse gases are gases that absorb radiation at infrared wavelengths. Those -- the radiation that's received from the sun, the energy peaks in the visible spectrum at wavelengths of about half a micron, but the energy is then reradiated into space as thermal or heat radiation, which is at longer wavelengths, the peak of the thermal emission spectrum being at 10 to 20 microns in wavelength.

And greenhouse gases absorb the heat radiation that's emitted by the Earth's surface and by the atmosphere. And as a result, they trap that heat radiation, and if you increase the amount of these greenhouse gases in the atmosphere, that will be a mechanism for making a surface warmer, and we can measure that forcing in the same way that we measure the change in -- the effect of changing the sun's brightness.

Because we -- the physics of this infrared radiation being returned to space is very well understood. We can

calculate with an accuracy of about 10 percent the impact of increasing greenhouse gases on the outgoing radiation; and if you double the amount of carbon dioxide in the atmosphere, it causes a forcing of about 4 watts per meter squared. So that's equivalent to increasing the brightness of the sun by 2 percent. And that's -- so that's -- and as you can see, that would be a fairly large forcing.

Q What is the concentration as we sit here today of carbon dioxide in the ambient atmosphere?

A Averaged over the world, it's about 383 parts per million, which compares with 280 in the preindustrial era. So for the last 8 or 10,000 years, it was approximately 280,000 parts per million. And it began to increase in the -- significantly in the 17 and 1800s, and it's been increasing very rapidly in the last 30 years. It began to be measured very accurately in 1958 by Dave Keeling, and at that time it was 315. So it increased -- from 1750 to 1958 it increased from 280 to 315. That's about 35 parts per million. But since 1958 it's increased to 383. So most of the increase has been in the last few decades.

Q And where is that extra carbon dioxide coming from?

A It is primarily coming from fossil fuel burning. There is a significant additional contribution from deforestation, from disturbance of the soils which contain carbon, but the best estimates from carbon cycle models are that about 20

PPM -- of this increase from 280 to 383, 103, about 20 of that may be due to other than fossil fuels. So about 80 percent is due to fossil fuel burning.

Q And --

THE COURT: Can I just ask a question?

MR. PAWA: Please.

THE COURT: Going back, you set the baseline at 280 in the 1700s and 1800s.

THE WITNESS: Yeah.

THE COURT: How do you actually calculate that? I mean, how do you come to that conclusion that there were -- that we're 280 -- you set it at 280?

THE WITNESS: The best measurements are -- are from the ice cores. There are bubbles of air trapped as the ice sheets on Greenland and Antarctica and, for that matter, even in some glaciers on mountains, as those are formed by snowfall piling up, it -- it gets -- as the snow piles higher and higher, it compresses and forms ice; and within the ice, bubbles of air are trapped, and we can drill into this ice sheet, and actually you can see annual layers of ice. So you can count back the date and find bubbles of air that have the -- are a sample of what the air was like at that given date.

Now, there is a -- you have to correct for the fact that it takes time for the snow to get high enough to

compress into ice, and until the bubble is sealed, until the ice seals the bubble, you can have circulation within that. So you have to correct for that time that it takes for -- so that's one -- there are other methods, also, but -- I'll actually show some results for a longer time period.

Q Dr. Hansen, how far back does the ice core record go?

A The ice core record now goes back about 700,000 years. There's hope that it may go back a million years in the next core, but so far that's how far we've gotten.

Q When was the last time the Earth had a carbon dioxide concentration in the atmosphere of 380 or 383 parts per million?

A That -- that is hard to say, because as I will show on a later chart, that is -- within the last million years it has never come anywhere close to that. You'll have to go back probably a few million years. It's harder -- we don't have ice cores going back a few million years, but there are other ways to estimate the CO2 at earlier times.

There are effects, for example, on nature of leaves. The number of -- nature of the stomata on the leaves changes as the amount of carbon dioxide in the atmosphere changes. So we have less accurate measures as we go back. So I would say it's been somewhere -- it has to have been more than a million years. Probably two to -- between 2 and 5 million years ago. You'd have to go back that far to find an amount

as great as today, 383 parts per million.
Q Sticking with the more accurate ice core records, what's the highest level of carbon dioxide found going back 6 or 700,000 years in the Earth's atmosphere other than -- other than today?
A It's not much higher than the 280. We can look at a graph -- it might be 290, but the variations from the ice age to the interglacial -- from the -- again, I think it might be helpful if we would go to the next charts, because these questions will be answered naturally by the graphs that I have.
Q All right. Before we go there, could you explain the concept of climate sensitivity, which I understand the -- some of your other graphs and charts refer to?
A In fact, that's -- that's what I would like to show on my next chart, I believe. Yeah. Climate sensitivity, to answer your question directly first, is the amount of global warming for a given unit of forcing. So we measure it in degrees Celsius per watt per meter squared. So I talked about doubled CO2, which is four watts per meter squared. That's -- that's often used as the canonical case or a standard experiment.
And you ask how much warmer will the world get if we double carbon dioxide. There was a classical study by the National Academy of Sciences in 1979 chaired by Jule

Charney, a famous professor at MIT, and they estimated that the world would get 3 degrees Celsius warmer, about 5-1/2 degrees Fahrenheit, if you doubled the carbon dioxide. But their uncertainty bar was very large, because it was derived from climate models. Partly from the climate model at our institute and at Princeton University.

But now we have a better way to estimate this climate sensitivity, and that's to look at the history of the Earth. And this graph that we have here shows the temperature in Antarctica as determined from an ice core which in this case went back a little more than 400,000 years.

So time is running from the left to the right. The present is the rightmost point. The so-called Holocene period. We've been in this interglacial period for almost 12,000 years now. And in order to estimate climate sensitivity, we can compare this Holocene, the present interglacial period, with the preceding ice age which peaked 20,000 years ago. And as I mentioned during that ice age 20,000 years ago, there was an ice sheet that covered Canada and reached down into the United States, and there was another ice sheet over northern Europe, and you can see that the temperature in Antarctica was about 8 degrees Celsius colder during the ice age than it has been in the last 12,000 years.

But we know that both during the ice age and during the

present interglacial period the planet is approximately in radiation balance with space. By that I mean the amount of energy that's radiated to space by the Earth is the same as the amount of energy that the Earth is absorbing from the sun. Because if it weren't the same, then -- if it were greater, a greater amount absorbed, then the planet would warm up until it balanced it, until they were in balance.

And so we can compare these two periods, because the things that cause the Earth to be warmer today can either be in the atmosphere or on the surface of the planet. It could also be that the sun became brighter, but we know that the sun is not flickering enough to cause 10 degrees Celsius temperature changes. We know that the sun is a well-behaved, main sequence star, and its output does vary slightly. It's increased 10 percent over the last billion years, but that's only a hundredth of a percent in a million years. It's negligible on these time scales.

So the changes have to be in the atmosphere on the surface. And in fact, we know those because we have samples of the atmosphere today and 20,000 years ago from these bubbles of air. And there are more greenhouse gases today than there were 20,000 years ago. There's more of all the long-lived greenhouse gases, carbon dioxide, methane, and nitrous oxide, there are more in the present interglacial period. And we know accurately the changes.

Also, the surface was different because -- partly because of this ice sheet that covered Canada but also because the distribution of force, the vegetation, were different then, and we have geologic records of that, and even the coastline was different, because there was a 120-meter fall in sea level because of all the water that's locked in Canada.

So the next chart shows what --

Q Before we go on, just to back up, I want to make sure. It may be clear, but just to be sure, to define the X and Y-axis, that, for example, the age kyr BP --

A Yes.

Q -- is clear --

A This chart shows the temperature in Antarctica as a function of time over the last 430,000 years, and you can see it has these large fluctuations from warm interglacial periods and then it slowly gets colder over a period of 100,000 years. And then suddenly gets warmer. And then gets colder again. So it fluctuates between ice ages, interglacial periods, the warm periods, and the glacial ice ages. And what I'm looking at to start with is just to compare the current interglacial with the last ice age 20,000 years ago.

And the next chart shows the same -- the temperature at the bottom, the bottom curve is the same temperature curve,

Antarctica, but the same ice core also has the record of these greenhouse gases, and you can see that when the planet was warmer, there was more carbon dioxide in the atmosphere. And there was more methane in the atmosphere. There's a strong correlation between the greenhouse gas curves and the temperature curve. But what I want to do first is just compare the present with 20,000 years ago. And on the next chart I summarize the two changes. If you go one more chart.

The forcing due to the change in the surface albedo - that's the reflectivity of the surface - because these ice sheets are brighter than the normal surface, they reflect sunlight, and that -- the change in the amount of energy absorbed by the Earth because of these brighter surfaces is 3-1/2 watts per meter squared averaged over the planet. The greenhouse effect, the change due to the larger amount of greenhouse gases presently compared to the ice age is a forcing of 2-1/2 watts per meter squared. So there's a total forcing of about 6-1/2 watts per meter squared, which is maintaining a planet 5-degrees temperature change. So that implies a sensitivity of three-quarters of a degree Celsius for each watt of forcing.

Well, that happens to agree with Charney's, with the climate models, because the climate models say 3 degrees for doubled CO2, and doubled CO2 is four watts of forcing. So

it's three-quarters of a degree for each watt of forcing.

But the nice thing about this empirical way of estimating the sensitivity is that we know it includes all of the physics. Whatever is -- there are things that are hard to model in climate models, like clouds, and so for many years people have argued do we have clouds simulated correctly in climate models, and you can never be certain, but clouds did -- whenever -- they existed in this real-world experiment, and in the real-world empirical evaluation of sensitivity, we get the same result as from the climate models, about three-quarters of a degree for each watt of forcing. And so that's a useful check on the climate models.

Now, could I have the next one, please? We can -- so we got this empirical information by comparing just two points in time, the current interglacial and the last ice age, but we now have information on this entire 400,000-year period, which lets us check things more decisively. Because we now have a measure of how sea level changed over that entire period from an analysis in the last few years, and that's shown in the top chart. And you can see that sea level has changed by more than 100 meters, going from -- as a function of time over this last 400,000 years. During the ice ages, sea level is lower because the water is locked up on ice sheets on the continents.

That allows us -- the knowledge of the sea level allows us to know how big the ice sheets are. So we can calculate -- for this entire period we can calculate the climate forcing due to the ice sheets, due to the fact that the surface is becoming brighter. And that's shown in this -- in the middle graph by the blue curve, and we can calculate the climate forcing due to the greenhouse gases because we have a record of the greenhouse gases over that entire 400,000-year period.

So if we just add up those two forcings, multiply them times three-quarters of a degree for each watt of forcing, we get a predicted temperature for the entire 400,000-year period. And that predicted temperature is shown by the blue curve for the -- in the bottom graph, the blue curve is the calculated temperature and the observed temperature based on the measurements in the Antarctic ice core.

In going from an ice age to an interglacial period, the temperature changes -- at the poles changes by 8 to 10 degrees Celsius, but at the equator, the temperature change from an ice age to the interglacial is only about 3 to 4 degrees. And averaged over the planet, it's about half of what it is at the poles. The amplification at the poles is because of positive feedbacks, as I mentioned. The biggest positive feedback is that as the planet gets warmer, you have less ice and snow, and so the planet absorbs more

energy at those high latitudes.

So anyway, so to get the estimated global temperature, we've divided the polar temperature by two. And you can see that in fact the -- these two mechanisms, the ice sheet area and the greenhouse gas changes as a function of time, do a good job of accounting for the temperature change over the entire 400,000-year period, which adds additional confidence to the conclusion that the sensitivity is roughly three-quarters of a degree for each watt of forcing.

Q Have you prepared additional charts on the topic of climate sensitivity?

A Yeah. So let's -- and -- well, this -- this -- just to -- I'd like to illustrate one important point is that if you look carefully at the greenhouse gas changes and the temperature changes, you'll find -- over this 400,000-year period, you'll find that the temperature changes slightly lead the greenhouse gas changes. So that is often used by senators in Congress to say that, Well, greenhouse gases aren't causing temperature to change; it's the temperature that's causing greenhouse gas to change.

Well, that's true on the time scale of the ice ages. As the planet gets warmer, greenhouse gases come out of the soil and out of the ocean. It's a well understood phenomenon. As the ocean gets warmer, just like your soda pop, if you warm it up, the CO2 in the soda will come out.

It -- the amount that the ocean can dissolve depends upon the temperature. So that's -- that's true on this time scale the greenhouse gases are slightly lagging the temperature change, but in fact they're merely synchronous. As you can see in this graph, the CO2 changes are almost synchronous on the time scale -- on the geological time scales. And in fact, they are one of the two mechanisms for that temperature change. So the temperature change is very large. It's amplified by the greenhouse gas changes.

So could I go to the next one now? But what's causing those changes of -- you know, if the greenhouse gas changes are feedbacks, what is basically causing this climate change over several hundred thousand years? Well, that's very well understood.

It was -- a famous paper in 1976 was by Hays, Imbrie, and Shackleton in which they showed that all of these fluctuations in the Earth's climate are very highly correlated with changes in the Earth's orbit, which affects the seasonal distribution of sunlight on the surface of the Earth. The principal factor is the tilt of the Earth's spin axis relative to the plane of the Earth's orbit.

And you can easily imagine that as the spin axis -- and the reason these -- the Earth's orbit is changing is because of the gravitational effect of other planets on the Earth's orbit. So Jupiter and Saturn in particular are the heavy

planets that pull -- tugging on the Earth, and Venus actually has some effect, also, because it comes so close to the Earth. But this is a very well understood, many-bodied problem.

Just using Newton's gravitational law, you can calculate the effect of these other planets on the Earth's orbit, and the spin axis of the -- the Earth will wobble by plus or minus 1 degree. Right now the Earth's spin axis is about 23-1/2 degrees to the plane of the orbit. But at times it's tilted more, and when it's tilted more, that exposes the polar ice caps to more sunlight, and so it tends to melt these polar ice caps. In fact, it melts them on both -- both poles, because six months later, as the Earth is going around the sun, the other pole is exposed to more sunlight if the tilt is greater.

So that -- the instigator of these paleoclimate changes is primarily changes in the Earth's orbit. And -- which will melt -- make -- melt the ice sheets and -- and in turn, as the planet gets warmer, then greenhouse gases come out of the ocean and out of the soil. And this is -- this is well understood. Details of exactly how the carbon cycle works and how much the ocean is contributing relative to soils and plants is still -- there are many things to be understood better, but the essence of it is very well understood.

So could I have the next one? This -- just to make

clear, this -- again, this -- this graph -- and I'm sorry, this is a little esoteric in the sense this is oxygen isotope. The thing is that you would like to see how this climate has been changing at longer time scales than just the last 400,000 years because -- for the reason that we mentioned earlier. CO2 was never much more -- I forgot to look at the graph as we went past it, but at the peak of any of those interglacial periods, it's not more than about 290 parts per million. So there's not much more than the 280 that we started out with in the current one.

So if you want to -- if you want to see something that's comparable to where we're headed now and where we are in 2007, you've got to go back further in time. And to do that, we have to look at ocean cores rather than ice cores, because the ice cores only go back less than a million years.

Q Explain what an ocean core is.

A Now, an ocean core is a sediment -- again, you obtain the core by just having a piston, a hollow tube, pushed into the ocean sediments, and you take out this core of material. That material was laid down over time. As the microscopic animals living in the ocean, as they -- as they die and their shells sink to the bottom of the ocean, they become part of the sediment, the shells of -- in this case it's foraminifera, but it's microscopic animals with -- with

shells. And you can measure the composition of the shells and the isotopic composition of the carbon and oxygen components, and in the case of this delta 18O, that's a measure of both temperature and sea level. And so as it goes down, it's becoming colder. And sea level is becoming lower.

So what we see over this last -- this is 3-1/2 million years, now, going from, on the left, 3-1/2 million years ago to the present at zero. And the frequency -- and so each of these fluctuations up and down is changing from an interglacial to a glacial, and the period -- if you look carefully at these, you'll see that the period of these fluctuations is 41,000 years. That's the period by which this tilt of the Earth's axis changes. It changes regularly at 41,000 years. Going from 22-1/2 to 24-1/2 and back. And the ice is repeatedly melting and reforming as -- as the Earth's spin axis changes. But the other -- so -- so you see very nicely this 41,000-year periodicity.

But in addition, there's a slow cooling over that period. And that is believed to be associated with the fact that carbon dioxide, greenhouse gases were decreasing over this period. And the interesting thing, important thing to note about when you go back to this period 3-1/2 million years ago, which is the middle Pliocene, as it's called, the Earth was 2 to 3 degrees Celsius warmer than it is now, so

it's a very relevant time to look at, because that's the magnitude of global warming that we're expecting if we follow business as usual. And it should be noted that at that time sea level was about 25 meters higher than it is now.

So 2 to 3 degrees Celsius global warming is really a different planet. At that time there was no ice in the Arctic Ocean in the warm season, and sea level was approximately 80 feet higher than it is now. So it's not -- that's a magnitude of climate change which we would like to avoid given the fact -- I think, given the fact that we have such a huge infrastructure around our coastlines and more than a billion people living within an elevation of 25 meters of sea level.

But let's -- let's go on to the next one. So now --

Q This -- go ahead. I was just going to ask, does this one also relate to climate sensitivity?

A Well, this -- this is -- this is a repetition of three curves that I already showed, but now I've added on to these the changes in the last hundred years. And you can see that in the last hundred years CO2 and methane have increased far outside the range of -- of any of the previous interglacial periods. And by the way, I should slightly correct myself, because now we can see again the carbon dioxide in the previous interglacial periods, and you can see that the

interglacial period 320,000 years ago or 330,000 years ago, the CO2 might have been as high as 300 during that interglacial, and that interglacial you can see was warmer than the present one.

Q In terms of radiative forcing, as we sit here today, what's the most important greenhouse gas? Is it methane or carbon dioxide?

A Well, carbon dioxide is the most important anthropogenically because we're putting so much of it up there. On a per-molecule basis, methane is more powerful than CO2, but we're -- by 20 or 30 times, but we're putting so many more CO2 molecules up there that CO2 is -- is the more important. And CO2 is particularly important because of its very long lifetime.

Methane has a lifetime of about 10 to 12 years, but CO2, the very interesting, important property of CO2 is that although about half of it -- if we put a pulse into the atmosphere by burning fossil fuels or whatever, about half of that will be taken up by the -- by the ocean and the soils within about 25 years. Twenty-five to thirty years. But after a century, still a third of it is there. And after 500 years still about a quarter is in the atmosphere because the CO2 that's taken up by the ocean exerts a back pressure on the atmosphere and makes it difficult for the remaining carbon dioxide to be taken up by the ocean.

It can only be taken up after the ocean -- well, some of -- some additional can be taken up as the ocean mixes down, but -- but still there's a limit -- a significant fraction will remain in the atmosphere until the sediments -- the carbon dioxide has been deposited in the sediments in the ocean, and that requires thousands of years.

And, therefore, CO2 is the one that's of greatest concern just because a substantial fraction of it -- I say a quarter of it will remain there for an eternity. If I define 500 years as an eternity, then about a quarter of it stays there that long.

Q All right. Have you prepared another slide on the implications of paleoforcings and their response?

A Yeah. Could we see the next one? So this just summarizes the implications from the paleodata. What we see is that the chief mechanisms for these climate changes over the last hundreds of thousands of years have been greenhouse gases and the ice sheet area, but they've been changing as feedbacks to this instigator, which is the Earth orbital changes.

And so what this tells us is that climate on these longtime scales is very sensitive to even small forces, and now the human-made forcings are much larger than the natural forcings that drove the glacial to interglacial climate

changes. So the bottom line is that humans now control a global climate.

Q Have you also prepared an analysis of global temperature change in the industrial era?

A Yes. So then the logical -- so what we've been looking at are really -- in the case of a paleoclimate, is an empirical example when we give the system long enough to respond. I mentioned at the very beginning that the ocean -- because it's four kilometers deep, when you do force the system, it takes it time to respond. In fact, we can look at the response time.

In the case of any forcing, whether it's a change in the brightness of the sun or whatever, it -- after about 30 years you have about half of the surface temperature response. After 100 years you've got about 75 percent of the response. And it takes -- after 500 years you've got almost all the response.

But if we want to look at the effect of changes in greenhouse gases now, we have to take account of this finite response time of the system. And that's what climate models do naturally. Your model includes the atmosphere and the ocean and the dynamics of these, and so you get a -- you can calculate the temporal response of a transient forcing. And we have a pretty good knowledge of the largest forcings over the last century.

This top graph shows several different forcings that are occurring -- that have occurred in the last century. The large positive one is the increasing greenhouse gases, and over the last few decades that has become very large and has become the dominant forcing. There are natural forcings as well as man-made ones.

The blue curve that's fluctuating is due to volcanos. When a volcano goes off, it sends a lot of sulfur dioxide into the stratosphere, and that condenses into sulfuric acid droplets, and that would cause colorful sunsets after a volcano. But there was a huge one in Krakatau in 1883, and then there was Agung in 1963. That was actually the one that I studied when I was a senior and a first-year graduate student using a telescope outside Iowa city. But there's other large volcanos: El Chichon in 1982 and then Pinatubo in 1991.

But anyway, when we use those --

THE COURT: Mount St. Helen didn't make -- didn't make the chart?

THE WITNESS: No, it didn't. It put almost nothing up there. Essentially it was such a disappointment from a climate standpoint. It -- Mount St. Helens blew out the side of a mountain, but there was very little sulfur in the gases that came out of it. Some -- the amount of sulfur dioxide that's put into the stratosphere depends on how much

stuff is blown up and gets into the stratosphere, but also depends upon how much of that stuff -- how much sulfur dioxide is included in what gets up there, and Mount St. Helens was more than 100 times smaller than these big volcanos in terms of its sulfuric acid.

Q So, Dr. Hansen, what's the significance of this chart graph for the purpose of analyzing climate change in the industrial era?

A Right. So then if we -- if we use a climate model that has a sensitivity of three-quarters of a degree for each watt of forcing, then we calculate these temperatures shown in the bottom graph, and that can be compared with the observed temperature. The observed temperature is the blue asterisk connected by a blue line. And you can see that the model actually does a good job of simulating the temperature over the last hundred years. That gives us some confidence in using the same model to just extend the calculations into the future and thereby get a measure, an estimate, of what the effect will be of future greenhouse gases, future increases in greenhouse gases. And so we use both business-as-usual scenarios for the future and an alternative scenario, and that's shown on the next chart.

Back up one chart. You went two charts. There. That one.

Yeah. This shows -- again, it -- it starts in 1850 and

goes up to year 2100. So for the period up to 2005, it's using the observed forcings, and then for the future we use the IPCC, the Intergovernmental Panel on Climate Change, their scenarios for the future, which are basically the business-as-usual scenarios.

The dark blue lines are business-as-usual scenarios, and that's -- "business as usual" is defined as approximately 2 percent per year increases in the amount of fossil fuel CO2 emissions, because that's what the increases have been in the last decade; and in fact since the 1970s the CO2 emissions have been increasing approximately 2 percent per year.

So if we continue that rate into the future, we will get these scenarios that are called -- like A1B, A1B would be the typical business-as-usual scenario. A2 is also similar to that for the next half century. But -- and those give us global warming of 2 to 3 degrees Celsius by the end of the century.

Q Dr. Hansen, do any of the IPCC scenarios include assumptions of legal regulations on greenhouse gases?

A No. Business-as-usual scenario is what you would expect if there were no regulations.

Now, then I like to contrast that with what I call the alternative scenario. The alternative scenario is something -- is a scenario that we published in year 2000.

It was designed to try to keep -- the forcings were designed to keep global warming from exceeding about 1 degree Celsius in the future, and in order to do that under the assumption that climate sensitivity is three-quarters of a degree for each watt, you need to keep additional forcing less than 1-1/2 watts. And so this scenario would have carbon dioxide peaking at about 450 or 475 parts per million if you decrease methane. But that is a scenario that's significantly less carbon dioxide than the common business-as-usual scenarios. And we can look at the consequences of these different scenarios, which I do on subsequent charts.

Q Have you attempted to define for the Court in your opinion what would constitute dangerous human or anthropogenic interference with the climate system?

A Yeah. I think that's -- that's a central question. In fact, that is naturally raised by the Framework Convention on Climate Change, which was agreed to by -- in 1992, 15 years ago, by essentially all nations in the world, including the United States. The Framework Convention has the objective of stabilizing greenhouse gas emissions at a level that would prevent dangerous human-made interference with the climate system, and so that's a natural subject, therefore, to try to define, Well, what does that mean? What is a dangerous level?

Q Okay.

A And so that's what we're trying to do as we look at these different scenarios. And you have to have some criteria for what is dangerous.

Q Have you attempted to define such criteria?

A Yes, I have. And the next chart summarizes the criteria change -- should be metrics for defining "dangerous." The reason -- I think that sea level -- ice sheet disintegration should be an important metric because it's irreversible. If Greenland or West Antarctic Ice Sheet disintegrates, it would take many thousands of years to regrow it by any natural process. And so for all practical purposes, that's irreversible. And the consequences are so dramatic that I think this should be one of the key metrics.

And also I think that extermination of a species is also an important metric because, again, it's irreversible. Sometimes called euphemistically reduction in biological diversity. But in any case, it's irreversible. And so I use that as another metric for dangerous.

And there are -- but in terms of near-term changes that people will feel, the regional climate disruptions are also very important. So even though those are not irreversible in a strict sense, they're also important, and I think they're an important metric to look at, and so I have looked at these different metrics.

Q Do you have slides on all three of these metrics?

A Yes, I do. This is a --

Q Is this sea level rise?

A This is -- no. This is the temperature -- this is related to sea level rise, but what it is is the temperature in the warm pool. The warmest place on the planet is in the western equatorial Pacific Ocean, and that's an extremely important region because that region determines the heat transport to higher latitudes in the atmosphere and also in the ocean. And if you're -- you would like -- what we would like to have is a graph of the global temperature change for very long periods, but, of course, it's very hard to get a global average. But if you're going to measure the temperature at one place, this is probably the most important place to do it.

And we do have temperature record here from -- again, from ocean cores. And this is the temperature going from 1.3 million years ago up to the present, and the time scale has been expanded on the right side of the graph so you can see the present would just be one point if we didn't expand that. But you can see that, again, what's happening over this entire million years, the temperature is going up and down as we're going from one of these ice ages to an interglacial period; but what we can see that -- is that the present temperature -- in just the last hundred years the temperature has increased to a point that we're within less

than 1 degree of the warmest interglacial period in this last 1.3 million years.

Q Celsius?

A 1 degree Celsius of the warmest. And that's -- that's part of the basis for saying we really -- it would be dangerous to go to global warming of more than that, because we know that some of these interglacial periods were warmer than the present one, but at most, not more than a degree warmer. And if we stay within that range, it's perhaps less dangerous. It's not as dangerous as if we go to 2 or 3 degrees, because as I mentioned earlier, 2 or 3 degrees means you're back at the conditions of the middle Pliocene when sea level was 80 feet higher.

Q What does SST stand for on this chart?

A Sea surface temperature. And again, that's measured by these microscopic animals that live at the sea surface and when they die their shells sink to the ocean.

Q Do you also have some charts dealing with the issue of sea level rise?

A So just one more comment by this. During some of these interglacials we have evidence that sea level was a few meters higher, so having warming of 1 degree has some -- I'm not saying there's no danger associated with that, but at least it's not 25 meters.

Q Twenty-five meters of...?

A Sea level. So let's go to the next one. Now, the reason we've become very concerned about sea level is not only looking at these paleoclimate records which tell us that warming of a few degrees is going to cause big sea level change, but the question is then the speed at which ice sheets can disintegrate. That's the big issue. No one --

MR. CLUBOK: Your Honor, I apologize for interrupting. I was going to try to not interrupt Dr. Hansen. But I do want to -- and I think it's clear for the record, but because there were some issues about what we did with Daubert before, maybe I just should say it again so it's crystal clear.

We believe there is a Daubert issue with respect to Dr. Hansen's testimony as to the 25-meter sea rise. We think that's not -- does not satisfy the standards under Daubert, and we raised this issue in a -- as you know, in a motion in limine, and my understanding was that instead of having the Daubert hearing in advance of the trial, we would have Dr. Hansen testify, our objection's preserved, and then either in the course of the trial or in posttrial briefing or whenever we're permitted to present our Daubert evidence, we will have that issue heard. That's -- had been my understanding, and I just wanted to raise this issue so there's not a question that tomorrow we waived our Daubert

objection somehow.

THE COURT: You're not waiving your Daubert objections.

That's your understanding; is it not?

MR. PAWA: I believe they did make a Daubert objection. I'm trying to recall exactly how Your Honor handled it. If they want to renew it, I suppose they can renew it.

THE COURT: Well, and clearly if there's evidence to be introduced during the course of the trial, the plaintiff can do that, and there may be supplemental briefings on that particular issue.

MR. PAWA: Thank you, Your Honor.

THE COURT: All right. Go ahead.

MR. CLUBOK: Thank you, Your Honor.

THE WITNESS: I should perhaps clarify a couple of things, then. The -- the 25 meters, I should say that the scientific literature indicates 25 plus or minus 10 meters, so between 15 and 35 meters. So there is a fairly big bar on exactly how sea level -- how high it was during middle Pliocene, but it was much higher.

Now, the issue -- the other aspect of that is, well, how long. That's -- and they're really -- although the public may have the impression now that there's a big disagreement about sea level rise, because, for example, in

the IPCC report that's coming out this year, the only numbers that they mention are only of the order of 20 or 30 or 40 or 50 centimeters. I don't remember exactly. But they specifically decline to give an estimate for contribution to sea level from these ice sheets.

They calculate only the contributions due to thermal expansion. As the ocean gets warmer, it expands a bit, and the mountain glaciers are melting, and that is happening at a very systematic way, which you can estimate how much it will continue to happen. But because this problem is so difficult as to how long it takes an ice sheet to respond to a changed forcing, they have decided not to do it in this report. It's going to -- but in fact, they're going to say that eventually the sea level rise due to this business-as-usual warming will --

MR. CLUBOK: Objection, Your Honor. I'm -- first of all, we're in the midst of a narrative. It's difficult somewhat for me to continue to object because it's not the normal question-answer format, but I think I'm hearing -- I think I'm hearing Dr. Hansen about to testify as to hearsay that he expects will be offered --

THE WITNESS: Okay. I can take back that word. I can say what is actually in the report.

THE COURT: First of all, this, generally speaking, is not hearsay if he is relying upon this as the

basis of his opinion. Are you suggesting -- well --

MR. CLUBOK: I just want to understand if he's saying what's going to be in the new -- there's a difference between Dr. Hansen testifying about his opinion and what he's relying upon and predicting what he says somebody is going to put in a report, which I'm not sure that's --

THE WITNESS: Okay. I don't need to say anything about what -- make any predictions about what people will say.

THE COURT: Okay. Go ahead.

THE WITNESS: I'll just say that there's not a disagreement. The people who do not believe that there will be a large sea level rise in the next several decades or this century do not disagree that there will be a large sea level rise. It's just an issue of how long it takes the ice sheets to respond.

In the paleoclimate case, some of the sea level changes occurred over millennia. And the models that were developed to try to simulate the paleoclimate case respond on millennial time scales. But they do not include essential physics of the ice sheets that we now recognize must be included, and all of the ice sheet experts agree on this. They agree they have no model to simulate the disintegration of an ice sheet.

And so that's the reason that IPCC decided not to

try to give a number. They just don't have a basis for doing it. But there's no disagreement that if you had global warming a few degrees Celsius, eventually you would get very large sea level rises. It's just an issue of how long it will take. But now we have evidence that allows us to get a better understanding of that, and that's the evidence of -- from measurements being made in the last few decades, and especially in the last few years.

This particular chart shows the area with summer melt on Greenland, and the two maps show the area with summer map in 1992 and in 2002. The red area is where there was meltwater on the ice sheet during those summers. And that's observed from satellites. And it -- it fluctuates from year to year, but it has generally been increasing. And in year 2005 it was even larger than in 2002.

And could I have the next chart? The effect of -- so this is a photo of meltwater on Greenland. The meltwater in general does not run off the edge of the ice sheet into the ocean. It -- it finds the lowest spot and it burrows a hole through the base of the ice sheet, and this is one of those holes where meltwater is rushing down the hole.

And -- could I have the next chart? The effect of this meltwater is to lubricate the base of the ice sheet, and it speeds up this discharge of giant icebergs to the ocean. This is the largest ice stream on Greenland, and the

flux of icebergs out that ice stream has doubled in the last five years.

Could I have the next chart, please? And there have been the uncertainty about what is actually happening to the mass of Greenland, because as the planet gets warmer, it has been argued by some people, correctly, that the atmosphere contains more water vapor and, therefore, you'll get more snowfall in the center of the ice sheet and it will grow faster. So you've got two competing processes: Increased melting and discharge of icebergs, but also increased growth of the center of the ice sheet.

Q Is there -- is there --

A Now --

Q Is there evidence with respect to which of those processes is greater?

A Well, that -- that's what's shown, in fact, by this chart. Because this -- we now have this spectacular satellite called GRACE. It's a gravity satellite. It measures the gravitational field of the Earth with such precision that you can see changes in the mass of the Greenland ice sheet and the Antarctic ice sheet. And that's what's shown on this graph.

Each year -- it goes up during the winter as the added snowfall makes the Greenland ice sheet heavier, and then during the summer the melting reduces the mass of the ice

sheet. But there is a downward trend over this period, and there's now one year additional data. But it shows an average loss of about 150 cubic kilometers of ice per year.

So Greenland is, in fact, melting. It is losing mass at a rate of about 150 cubic kilometers. And Antarctica -- I don't remember the next chart --

Q 150 -- let me interrupt. 150 cubic kilometers per...?

A Per year.

Q And do you have additional empirical evidence with respect to what's happening on Greenland, Dr. Hansen?

A Yes. Could I refresh my -- oh, yes. This is actually an important point. There -- there are seismometers located all around the world. These are used to detect and measure -- to detect earthquakes and measure the strength of the earthquakes in Richter units. And what has been found is that earthquakes are beginning to occur on Greenland, and their number is increasing.

This bar chart shows that in 1993 there were six or seven, I believe seven, earthquakes on Greenland; and by 1999 it had doubled to 14; and by 2005 it had doubled again. What these earthquakes are caused by is a chunk of the ice -- ice sheet will surge forward downslope toward the ocean, and then it grinds to a halt on the solid land, and that registers as an earthquake. And the number of these earthquakes is increasing, and it's of concern to

glaciologists and anyone who's concerned about sea level because it indicates that, you know, it's consistent with a nonlinear process where the ice sheet is becoming less stable.

Could I have the next chart? This is just to illustrate why we don't want -- if we go to 3 degrees warming and then get the equilibrium response, however long that takes, it would mean the entire East Coast of the United States would be underwater and almost all of Florida. About 50 million people live in this area of the United States, but there are even more in places like Bangladesh, where the entire nation -- practically the entire nation would be underwater. And 250 million people in China. So it's not a -- obviously it's not a situation that we could adapt to. It would be a tremendous change.

Could I have the next chart.

THE COURT: This is on the assumption that the rise in sea level is 25 meters.

THE WITNESS: Yeah. Yeah.

Q Have you prepared a chart with respect to -- summarizing your conclusions on sea level rise?

A Yes. I think that's the next one. Yeah. Yeah. Well, so this question -- the scientific issue now, which we're -- is of great concern and which is a very difficult problem because -- the reason it's difficult is this is what I would

call a nonlinear problem, because there are multiple positive feedbacks. So if it reaches a point, it may disintegrate rapidly, and we know that this has happened. If we look at the history of the Earth, if we look -- if going from the last ice age, which peaked 18,000 years ago, to the current interglacial, there were times -- there was one time -- it's called Meltwater Pulse 1A. About 14,000 years ago, sea level went up about 20 meters in 400 years. So that's about 1 meter every 20 years.

So when ice sheets disintegrate --

Q I'm just going to move the mic a little closer to you.

A When ice sheets disintegrate, they -- they can disintegrate quite rapidly. Now, that ice sheet was the one on Canada which was at somewhat lower latitude than the Greenland ice sheet or the Antarctic ice sheet. But the forcing that drove that ice sheet disintegration was much smaller than what we're talking about with the human-made forcing.

THE COURT: But there comes a point at which -- I think you referred to this as your tipping point, or is the tip -- I shouldn't say "yours." Is the tipping point theory that you come to a certain point, then all of a sudden the changes become --

THE WITNESS: Become --

THE COURT: -- dramatically more rapid?

THE WITNESS: -- out of control. Right.

THE COURT: And how do you know where that point is, when that point arrives --

THE WITNESS: Yeah. That's the hard problem.

THE COURT: -- how predictable it is?

THE WITNESS: Well, that's the hard problem. That's why I argue that if we keep the warm -- the original thought behind the alternative scenario was, well, if we keep warming less than 1 degree, we probably don't pass the tipping point for the kind of sea level rise that we had in the middle Pliocene, because we know from these previous interglacial periods some of them were warmer than the present. And by perhaps almost 1 degree. And we didn't get 25-meter sea level rise. There were -- there was sea level rise, maybe even 5 meters. It's hard to measure it to that accuracy. But they're where the warmest interglacial sea level was higher.

But if the system is aiming to go just a few meters higher, then I can imagine that the time that it takes to get there is going to be longer, and you may not get multiple-meter sea level rise in the next century, but if it's aiming to go 25 meters higher, if the forcing is enough that it's going to eventually cause a 25-meter-high sea level rise, then I think that you would get multiple meters in the next century given the evidence that we have

for changes already beginning to occur.

And by the way, I showed maps for Greenland, but the ice sheet that I think is of greatest concern is the West Antarctic Ice Sheet, because the West Antarctic Ice Sheet is sitting on bedrock several hundred meters below sea level; so the ocean comes in direct contact with part of the West Antarctic Ice Sheet, and the -- there are ice shelves which -- which go out from the West Antarctic Ice Sheet down on the solid surface beneath sea level; but those ice shelves are now melting at a rate of several meters per year, and if -- I think there's a great danger that this West Antarctic Ice Sheet, we could pass the tipping point.

And West Antarctica has about seven meters of sea level in it, so I think it is -- in terms of the list of metrics for what constitutes dangerous, that's at the top of my list, because I think -- I'm even beginning to wonder if 1 degree Celsius is not -- is not dangerous on a long enough time scale. It's unclear to me whether 1 degree Celsius would not be dangerous itself. But 2 or 3 degrees Celsius is a guarantee for disaster.

THE COURT: Well, let me just make sure that I understand your testimony before you go off into the West Antarctic Ice Sheet. If there's an increase of 2 to 3 Celsius by the end of the century, your anticipation is that there would be a 25-meter rise in the sea level, but then

you suggested that into the next century beyond that you could reach the tipping point after the 25 --

THE WITNESS: No.

THE COURT: -- meters?

THE WITNESS: No, no. I'm sorry I was unclear.

THE COURT: Is the tipping point that sometime in advance of the 25 meters which results in --

THE WITNESS: Results in the 25.

THE COURT: -- the 25 meters?

THE WITNESS: Yeah. Okay. The tipping point, that's the point. Some scientists say, Well, we've already reached the tipping point. I don't -- I don't -- I don't think that's true, but I think we're getting very close.

THE COURT: By "tipping point" do you mean you get to a certain threshold and from that point on there's nothing that you really can do to stop the rapid increase in the -- the rapid rise in the sea level?

THE WITNESS: Yeah. The way I define a tipping point is you reach -- it's a point in the climate trajectory at which very little, if any, additional forcing is needed for substantial changes to occur. The dynamics of the system will carry you to substantial change with very little additional forcing, if any.

Q Dr. Hansen, is there evidence in the paleoclimate record for abrupt climate changes like these?

A Yes. I mentioned the one, Meltwater Pulse 1A, but that's just one. That's just one example. There are other -- there are multiple cases. In fact, the earliest graphs that I showed you, if you remember, the temperature change would go up very rapidly, and then it would take longer to go down. Well, the going up rapidly could be a few thousand years.

This is 400,000 years or longer on that diagram. So -- but within -- but the changes are huge over that few thousand years. You know, 100 meters of sea level rise. And the time scale for that response is roughly the time scale of the orbital change. So the time scale for the response is -- in that record is not dictated by an inherent time scale of an ice sheet to respond but, rather, it's dictated by the time scale of the forcing, in my opinion.

But in any case, we can say that there are multiple cases in the Earth's history at which sea level has gone up at these rates of several meters per century. So it can occur, and it has occurred many times in the past, and the forcings that drove those changes were smaller than the forcing we're talking about if we follow business as usual. So I think business as usual is extremely dangerous.

Q Dr. Hansen, do you have an opinion as to whether or not there is a risk of abrupt climate change in the 21st century as a result of anthropogenic greenhouse gas emissions?

A Yes. I think -- and the risk that I'm most concerned about is the one that we've been talking about the last half hour, sea level rise, but other -- other -- there are other issues. For example --

Q Let me ask you this. Is it possible to define the level of risk with precision?

A When we're talking about nonlinear problems where you have multiple positive feedbacks where you're worried about reaching tipping points, it's very difficult to predict when you will hit a very rapid response. It's not so difficult to predict that they will occur.

In fact, I would -- as I've written in an article that's about to be published, I consider it virtually certain. I think I -- at least in the draft I used the phrase it's a lead pipe cinch. If you go to 2 or 3 degrees Celsius, you're going to get large, sudden, rather rapid sea level rises. It's a question of when you're going to get them. That's very difficult to say. The nonlinear process, as I say, is difficult to predict when things collapse, but it's not difficult to say that they will.

Q Is that known as a climate surprise?

A Well, it may -- I don't know if I would call it a climate surprise. That phrase is used, but surprise would mean something that you don't expect, and in my case it's something I would expect.

Q Have you also prepared an opinion with respect to the risks of species extinction as a result of anthropogenic global warming?

A Yes. I think it's good that we say a little bit about that, also, if I could have the next chart, because -- well, yeah. Okay. Let's talk about species, because again, this is irreversible. Plants and animals can live within certain climatic zones. As you know, you don't plant in your yard something which you know will not survive. That's why you have handbooks that tell you where -- which zones a given tree can survive in, and likewise animals can live within certain climatic zones.

Now, extinctions are occurring relatively rapidly now because of stresses, mostly human-caused stresses, but climate change is an -- is an additional stress which is beginning to also affect species, and all biologists -- and as reflected in the upcoming IPCC report, the climate change that's projected with business as usual will become a major factor in causing extinction of a significant fraction of species on the planet, because -- plants and animals will attempt to migrate as climate changes, and there have been studies in the last ten years which show that -- that migrations are occurring at a rate of, on average, about 6 kilometers per decade.

But a given temperature line is now moving poleward at

a rate of about 50 to 60 kilometers per decade in land areas. So it's moving -- the zones are moving more rapidly than migrations are occurring, and also now many species are confined to specific reserves or because humans have taken over so much of the planet. And the -- so far this rapid movement of isotherms has been occurring for just 30 years now. The last 30 years. Most of the global warming has occurred in just the last 30 years. And so the total movement of an -- has been smaller than the size of a climatic zone that a species can exist in.

So in that case it doesn't threaten the survival of the species, but as this -- if we follow business as usual, this rate of migration of a given temperature line or isotherm will be as much as twice as large by the end of the century. And, of course, it will then be a cumulative over such a long period, so it would mean -- that's the basic reason for why we expect there would be stress on many species and many extinctions.

And if I could see the next chart. This is an example of a particular one. Well, the same thing -- isotherms in addition to moving poleward also move upward, so this is an example of a Mt. Graham red squirrel which exists on just one mountaintop in Arizona. These are so-called islands in the sky. It's a desert, but these mountains have green -- green areas on them, and the Mt. Graham red squirrel was

identified as a threatened species a decade or so ago.

Its number had been increasing up to more than 500, but one of the regional effects of global warming is that subtropical regions are becoming hotter and drier, and so -- and the western, southwest United States is included in subtropic, so that that region -- one of the consequences of becoming hotter and drier is there are more fires and stronger fires, and the -- so then there have been fires on this Mt. Graham, and so the lower portions that were green are now not recovering. It's just too hot. So the climate has changed and those forests are not coming back. So now the Mt. Graham red squirrel is down to about a hundred squirrels.

But -- but it's an example of what we're doing is pushing -- there are biologically diverse regions in the slopes and on the mountains, and what we're doing is pushing off the top of the mountain the species that live in -- in those regions, just as -- if I could have the next chart. Just as we are pushing off the planet those species that live at the high latitudes if we cause all the ice to melt in the Arctic, for example.

And as I say, when -- during the middle Pliocene when it was 2 to 3 degrees warmer there was no sea ice in the summer in the Arctic, so there are many species that would be threatened by global warming at the high latitudes.

Q What is the current scientific consensus on the future of the Arctic Ocean in the summertime as the century progresses, Dr. Hansen?

A Well, I think now they've come to the realization which we had already inferred from the U.S. history that 2 or 3 degrees Celsius means the loss of all ice in the warm season in the Arctic, all sea ice, and so that -- I mean, that's a huge change.

Q Have you also prepared some slides dealing with the issue of regional climate change, Dr. Hansen?

A Yes. I think I have one or two charts on that. Yeah. The one thing which is now agreed, for quite a few years all we could say was that, well, as the planet gets warmer, the effect on regional will be an increase in the extremes, because we know that increased heating of the surface tends to increase evaporation if you have water to evaporate.

So over the oceans, you obviously get more evaporation. But -- and so therefore the total rainfall increases, and the most extreme -- because the atmosphere contains more moisture, the most extreme rain events are heavier. But in those places and times when it's dry, the increased heating makes the dry conditions more extreme. So you get more extreme droughts.

But now in addition to just that general statement, we can say all of the -- all of the models agree that there's

an intensification of the climatic patterns of the rainfall belt in the tropics and the dry subtropical regions on both sides of the tropics, that these will become more intense. The atmosphere becomes more stable in the subtropics.

So that in the western United States and in the Mediterranean region and parts of Africa and much of Australia, you will get more intense dry conditions, and again, the history -- the paleoclimate data does show that when the Earth has been warmer, the western United States has had more intense droughts. Even superdrought conditions.

So that -- that's the kind of thing which you would expect this type of regional climate change, and this is particularly important for the water supply. So places -- and the melting of the ice in the mountains, the Andes and in the Himalayas and in the western United States, will reduce the runoff from the ice and snow in the summertime. So it's going to make a longer, drier summer. So it's going to affect the water supply for a very large number of people on the planet if we go to business as usual.

Q Do you also expect there will be changes in precipitation on a regional basis, Dr. Hansen?

A Yeah. So that's really what this is addressing, that we can say something about an increase in the rainfall in the tropical rain belt and the rainfall events at middle

latitudes will tend to be more intense. So instead of having a hundred-year flood every -- once a hundred years, you may have a few of them per a hundred years.

Q Do you have another slide on this topic, Dr. Hansen?

A I'm not sure. Let's go to the next one. Okay. So this is just a summary of what I've just said. So I think that -- I think that's the last one on the regional.

Q All right. Have you done a comparison of the alternative scenario you described earlier in the business-as-usual scenario?

A Yes.

Q Have you prepared charts on that topic, as well, Dr. Hansen?

A Yes. I think that I did. Can you show me -- yeah. Okay. Now, this -- this is -- this shows the annual increase in carbon dioxide beginning 1850 up to the present and projected for the next 50 years to year 2050, at least. And the annual increase was less than 1 part per million when Dave Keeling began his measurements in 1958, but you can see that by the present it's now 2 parts per million.

Each year the amount of CO2 is going up approximately 2 parts per million. It fluctuates from year to year because of the sinks. The ocean and -- and biosphere take up part of the anthropogenic emissions, and that sink fluctuates from year to year. But on the average the increase is now

about 2 parts per million per year.

If we follow business as usual, it will go up to about 4 parts per million per year by the middle of the century. That's what would imply, then, a global warming of about 3 degrees Celsius by the end of the century.

If we want to follow the alternative scenario, we've got to get CO2 growth to begin to decline, and this scenario was defined in an attempt to be something that's plausible. So we have it decreasing from what at the time, in the late 1990s, when we defined this, was 1.7 PPM per year, decreasing to 1.3 PPM by the middle of the century, and then decreasing more sharply so that by year 2100 CO2 stopped increasing. That would be stabilizing atmospheric composition as the Framework Convention and all countries in the world have agreed we need to do, and this would be stabilizing it at a level of 475 parts per million.

And this, then, leads to a global warming of about 8/10ths of a degree Celsius if climate sensitivity is 3 degrees for doubled CO2 or three-quarters of a degree for each watt. So this was -- so that's the sort of scenario that we would need to follow if we want to keep global warming less than 1 degree Celsius.

Could I have the next chart? Now, in the real world what is happening is that CO2 is -- the emissions are continuing to get greater each year. Between the end of

World War II and 1970s, the increase was about almost 5 percent a year, and it was in lockstep with economic growth. We used 5 percent more energy to get 5 percent more product.

Beginning in 1973, after the Arab oil embargo, there began to be efforts at energy efficiency, and it's particularly relevant, there's a significant increase in vehicle efficiencies. They approximately doubled because of regulations that were put in effect after the Arab oil embargo in the 1970s. And as a result, because of that, economic growth continued at a rate similar to what it had been before, but CO2 emissions, their rate of growth decreased to a little less than 2 percent per year.

Problem is, and now 2 percent per year is what is business as usual and, unfortunately, that's going to give us a different planet. And so we've got to figure out a way to go from 2 percent per year growth to some path in which we're getting some decrease in the annual emissions of CO2 to the atmosphere.

Q In formulating your opinion, Dr. Hansen, have you analogized this problem to the destruction of the ozone layer --

A Yeah. I think that's a useful comparison to -- because what needs to be done now is very similar to what was successfully done in the case of the ozone depletion.

Now, you may remember that in the -- this is actually

what got me out of planetary atmospheres and into the Earth's atmosphere was the realization in the 1970s that humans were putting chemicals into the atmosphere that were going to have a big effect on both the atmospheric chemistry and the atmosphere's -- and the Earth's climate.

Could I have the next chart, please? And those chemicals were chlorofluorocarbons. It was realized in 1973 when Sherry Rowland and Mario Molina reported that these chemicals, CFCs, could destroy stratospheric ozone and that would -- if we destroyed stratospheric ozone, then ultraviolet light would get to the Earth's surface, and it's very harmful to life, so that was a concern; and when they reported that, there was a prompt response.

Chlorofluorocarbon production had been increasing exponentially at about 8 to 10 percent per year up until 1973; and when that was realized, there was a halt in making any new factories to make chlorofluorocarbons. They continued to produce them at approximately the same rate, but they didn't make any new factories.

And then a decade later it was realized the ozone hole was discovered. And so then they said, Wow, this is not a theory. This is real. It's happening, and if we continue to make chlorofluorocarbons, we're going to destroy the ozone layer. So there was -- Montreal protocol was agreed upon.

That protocol had a relatively quick phaseout of chlorofluorocarbon production in the developed world. It put no restrictions on the developing world for ten years, because the developing world was just starting to make refrigerators, and they felt they had the right to have refrigerators because we had them in the West. So there was no restriction for ten years on the developing countries. And then after ten years they had -- they agreed that after ten years they would begin to do the same phaseout, and with the help -- with technological assistance from the developed world. And they did that, and you can see from these curves that chlorofluorocarbon production has declined by no more than a factor of 10.

It's -- it's -- this is a success story where the problem was identified and the communities in the world agreed to solve it, and it was done in a way that was felt that was fair to developing countries as well as developed countries.

Q And with this in mind, Dr. Hansen --

A And this was -- this was the analogy on which I designed the alternative scenario. So the idea on the alternative scenario was to flatten things out or get a slow, moderate decrease over the next several decades and then with new technologies to get more rapid decrease later in the century, and that's -- if I can have the next chart

to remind me what it is.

Oh, and that's -- the interesting thing is that that's exactly what the proposed improvements in vehicle efficiencies would do for U.S. vehicle emissions.

This graph is one that I made with summer students in which we took the National Research Council report for vehicle efficiencies -- the recommendations contained in the National Research Council report about five years ago for what vehicle efficiencies were practical with existing technology, and we took not the most extreme improvements that they said were possible but those which would basically pay for themselves depending on the assumed price for the -- for oil, but with those -- if those were phased in by -- over a 10-year period, the NRC recommendations, then what we find is that instead -- with the expected growth in vehicle number that is assumed to continue to grow rapidly, those improvements in the reduction in the amount of CO2 emissions per vehicle bring it -- actually cause a moderate decrease in the total emissions despite the increasing number of vehicles.

And that decrease continues for a few decades without any further improvements in vehicle performance. Conveniently by the time you get to 2040, then it starts to go back up again, because the number of vehicles is getting so large. But in reality, you would expect there would be

additional improvements in technology before 2040. So you can --

THE COURT: Let me just interrupt for a second, Doctor.

It is a little bit past 3 o'clock. Do you have much --

THE WITNESS: I think we're just about finished. Only one or two more charts.

MR. PAWA: There's only one or two more slides. Then I'm going to have just a few more questions and a few peer-reviewed articles to show him.

THE COURT: Okay. Well, let's take our break. We've gone a little bit longer than usual. So let's take a break at this point. Fifteen minutes. Then come back at that point.

MR. WYNN: Your Honor, could I be heard for one moment, please?

THE COURT: About what?

MR. WYNN: I'm sorry, Your Honor. But just in light of this morning's revelations with respect to Mr. -- Professor Patterson, I wanted to -- we're citing the case of Goose versus Gander. The defendants have been in contact with emeritus professor Mark Ross, who's also at the University of Michigan and I believe is a colleague of Dr. Patterson's, who has a long history in the analysis of

emissions in vehicles and the creation and improvement of the model of fuel use. Your Honor will doubtless recall that Mr. Duleep indicated to Mr. Drake that if --

THE COURT: Walk down the hall.

MR. WYNN: Walk down the hall.

THE COURT: Go walk down the hall.

MR. WYNN: Dr. Ross is happy to come here. He will be available for deposition on Monday afternoon, and he will testify very briefly, hopefully, on Tuesday. I will be in contact with Mr. Drake as soon as I get e-mail access and send all the appropriate documentation.

THE COURT: Well, maybe we should all go to Michigan.

MR. WYNN: It sounds fun to me, Your Honor.

MR. CLUBOK: Your Honor, we would stipulate to that. And we could drive there.

MR. WYNN: In fact, Your Honor --

THE COURT: In a minivan.

MR. CLUBOK: In a minivan. We will save a lot of fuel if you pack into one. It's so much better than flying.

THE COURT: That's fine.

MR. WYNN: In fact, thank you, Your Honor, but just in fact, when we're talking about things like that, perhaps the way to deal with this issue best given our time constraints would be if Dr. Patterson would put in a

declaration about his opinion about -- about Mr. Duleep's method and Dr. Ross could do the same. We can deal with it that way.

THE COURT: You might want to do that or you might want to do it in deposition and submit the depositions, because you're both coming fairly close to the deadline.

MR. WYNN: Your Honor, Mr. Kline couldn't have been more clear about that with me just a few minutes ago.

THE COURT: Anyway, but that can be an agreement between the two of you if you want to make that agreement. If not, we'll hear their testimony. Okay.

MR. WYNN: I'm sure we'll work together. Thank you, Your Honor.

MR. CLUBOK: Thank you, Your Honor.

(A recess was taken.)

THE COURT: Okay. Before we actually start, I've asked that a pro se letter that was sent to the Court be delivered to both sides. I have not read the letter, but I'm told that the applicant, who's a pro se person, wants to address the Court on the issues.

MR. HEMLEY: If it comes out of their time, it's all right with us.

THE COURT: I'm also told there's a unique part of Vermont.

MR. PAWA: We will not be seeking to depose this

person, Your Honor.

THE COURT: Okay. But I want to say that it has been docketed as a motion because it came in the form of a motion from a pro se person, and I have not reviewed it because it has some argument, and so I've told everyone not to tell me what's in it other than the fact that there was a request for an opportunity to speak. And obviously the Court's view is you can't just have people come in and speak, and so I would be inclined to decline the offer of the pro se person coming in to speak. In fact, I would -- unless one of the parties called her to testify, then that opportunity is not available to her. Okay?

All right. Dr. Hansen, you want to return to the stand?

THE WITNESS: Yes.

THE COURT: Good afternoon.

BY MR. PAWA:

Q Dr. Hansen, we're running short on time. I'll ask you to try to help us conserve time, if you would, please.

We're going to direct you back to the slide on U.S. auto and light truck emissions, which was 34. And I believe you were in the process of testifying on this slide. And if you could summarize the significance of this and particularly related to the AB 1493 regulation and emissions reductions under that regime.

A Yes. As I mentioned, the reductions in emissions that we chose were based on the NRC report, but not specifically on California, but -- in fact, they're closely related. These are actually slightly weaker. This is about 10 percent less reduction than California. So this shows that the California type of reductions would indeed move us off the path of business-as-usual vehicle emissions on to a path consistent with what I call the alternative scenario.

Q Have you also prepared a chart with respect to the historical emissions of carbon dioxide to the atmosphere?

A Yes. I believe my next chart is that. The point of this is that there's much -- the pie chart on the left shows that China is now almost as large as the United States in current emissions; and so it's often implied that China is equally responsible, but because of the fact that a large fraction of the CO2 stays in the air for an eternity, more than 500 years, the climate effect is proportional to the cumulative emissions, and in that case the pie chart on the right shows that the United States is responsible for well over three times more than any other country. So it does make sense. And we will continue to be primarily responsible for many decades even after China passes us. So it does make sense for us to reduce our emissions analogous to the way we worked in the case of the ozone problem and the chlorofluorocarbons.

Q Have you prepared a summary slide to summarize your testimony today?

A Yes. That's the final slide. And the basic point is that the technology exists to take us on a path consistent with this alternative scenario and keeping global warming under 1 degree Celsius. The next couple of decades could be with existing technology. We'll need, obviously -- for the stronger reductions later, we will need additional technologies, but we need to make use of what we have now to get on to a path that is consistent with keeping global warming in a range that has a chance of avoiding these dangerous climate effects.

And that does remind me, I should have also said in the case of species extinctions that it's not just the evidence from changes that are occurring now in the particular species that I mentioned, but looking at the history of the Earth, we -- there have been five or six global warming events comparable or somewhat larger than the global warming that's predicted for the end of the 21st century, and those global warming events resulted in extinction of a majority of species on the planet. So it's not just a theoretical. We have evidence that large global warming will result in -- in large extinctions.

So the -- the -- my -- but my bottom point is that the action is needed now, because even another decade of

business as usual, 2 percent per year compounded for another ten years would put us at 35 percent more emissions in 2015 than in the year 2000. That will put us 35 to 40 percent above this alternative scenario, and then it becomes impractical to get down to the alternative scenario because that would imply that you had in place the infrastructure producing that 35.

That would imply that you would have in place the infrastructure, power plants and vehicles, producing that emission at that rate. So that's why even a decade delay is a huge difference on the feasibility of the alternative scenario.

Q Dr. Hansen, is there a clear scientific consensus with respect to human beings causing global warming now?

A Yes, there is now. Twenty years ago that wasn't true, but now there is a clear consensus, yes.

Q And the clear consensus is...?

A That there is -- that there is global warming, yes, and it is --

Q And it's caused primarily by...?

A And it's caused primarily by increasing greenhouse gases.

Q And those come from...?

A And those come primarily from fossil fuel burning with carbon dioxide being by far the largest contributor.

Q Is there also a clear scientific consensus as to the issue of whether or not global warming already has begun to change the planet?
A There is -- again, I would say there is a clear consensus on that, yes, it is.
Q And is there a clear scientific consensus as to the issue of whether or not the level of warming in the future will be related to the level of greenhouse gas emissions?
A Yeah. There is a clear relationship between the magnitude of the increases in greenhouse gases and the expected warming.
Q And is it also true in the converse, that if you have less emissions, you would have less warming?
A Yes.
Q Is it true that any emissions reductions would have an effect on radiative forcing?
A Yes. That is a very straightforward thing independent of noise in the system. The forcing will be less if the gases are less.
Q Is that true whether or not you can actually measure the amount of radiative forcing with current technology?
A Yes. That's -- yes. Yes. There's a very clear relationship. The physics is straightforward.
Q Will the AB 1493 regulations, if implemented by the approximately dozen states that have adopted it, solve the

global warming problem?
A It's not going to stop global warming, no. It will have a reduction in the forcing, but by itself it will not solve the problem.
Q Did the emissions reductions of chlorofluorocarbons by the developed countries solve the ozone layer problem?
A The emissions reductions prevented us from going on a path which would have had chlorofluorocarbons actually exceeding carbon dioxide within a decade in terms of the largest climate forcing, so it made a huge difference, but it has not completely solved the problem yet. The ozone has not recovered, but it has -- the reduction in ozone has stopped increasing, and we -- and it's fitting with the model so that we can see over the next few decades the problem will be solved.
Q What are the scientific reasons with respect to the issue of global warming that the emissions reductions in your opinion, if it is your opinion, from the AB 1493 regulations are scientifically important?
A Well, I think that was what I was showing in terms of the rates of change that we need to achieve in order to get on a different path. This regulation is very consistent with that. So I -- I think it's -- it makes enormous sense, and I showed quantitatively that it is of the magnitude that's needed to make a difference on the time scale of the

next couple of decades. On a longer time scale you're going to need stronger reductions.

Q What significance, if any, is there of the AB 1493 regulations with respect to the issue of abrupt climate change?

A It's -- the discussion that we had a little earlier about tipping points is relevant to this. It's difficult to say, when you've passed tipping point, when you will cause positive feedbacks to cause an increasing response that in the case of some of these phenomena becomes out of your control, and that -- it's hard to say what is the straw that breaks the camel's back.

Q Will the AB 1493 regulations, in your opinion, contribute at some level to a reduction in risk of approaching and/or passing a tipping point?

A Sure. Even by themselves they make a difference, but they're likely to have a bigger effect on reductions in other parts of the United States and eventually, because our technology is related to what the rest of the world is going to use, it -- I would expect it would have a much bigger effect on the long run.

Q How much are we paying you for your time today, Dr. Hansen?

A Nothing.

Q How much have we paid you in the past for your time,

Dr. Hansen?

A Nothing.

MR. PAWA: The Court's indulgence?

THE COURT: Yes.

MR. PAWA: Your Honor, at this point our only further questioning for Dr. Hansen would be to hand him some exhibits which plaintiffs' counsel has stipulated to the admissibility of on the understanding these are all peer-reviewed journals, which we are representing to the Court that they are, and I'd just like to ask him if they reflect that his opinions as expressed here today have found their way into the peer-reviewed journals.

THE COURT: All right.

MR. PAWA: And the originals go to? You. Thank you.

Q Dr. Hansen, I've handed you a series of exhibits, and without going into any of the details, do these exhibits reflect your opinions as expressed today being included in peer-reviewed scientific literature?

A Yes. All of these are relevant to the discussions we've had in the last two hours.

MR. PAWA: We'd move to have them admitted, Your Honor.

THE COURT: All right. This is 2281, 82, 83, 84, 87, 90, 91, and 92?

MR. PAWA: Yes, Your Honor.

THE COURT: Okay. Any objection?

MR. CLUBOK: Your Honor, the documents themselves are hearsay. It's one thing for them to be marked as Dr. Hansen recognizing they are the collection of peer-reviewed journals that support his opinion, and that's -- that's one thing to have them identified as such. To actually be admitted into evidence as substantive evidence I think would violate the rules of hearsay.

THE COURT: Well, depending upon whether in fact he is relying upon the contents in some particular way.

MR. CLUBOK: Oh, he --

THE COURT: But that wasn't established. And these are -- many of these are articles written by him.

MR. PAWA: We're offering them only -- only for the purpose of establishing that some of his opinions as expressed here today are included in the peer-reviewed literature.

THE COURT: Oh, okay. So they're not being offered to prove the truth of the matter; they're being offered to corroborate the fact that his opinions today are in peer review literature for that limited purpose --

MR. PAWA: Precisely.

THE COURT: -- that's nonhearsay.

MR. CLUBOK: Well, actually, as I think about it,

the concern I have is -- first of all, that we have a collection of documents with no linkage, I believe, to the opinions; so now to rebut this, I suppose we're going to have to go through, try to interpret which of these documents match which of the opinions. I have some issues with this.

THE COURT: Well, I must have missed this. I thought there was a stipulation.

MR. PAWA: I thought so, too.

MR. CLUBOK: Well, I'm sorry. I had misunderstood. I had misunderstood. I thought that -- I thought I was being handed a collection of Dr. Hansen's papers that Dr. Hansen was just going to testify about and just say that this represents his own work in support of his testimony, so I'm sorry, but I misunderstood that. I now see there's different --

THE COURT: Well, there's one article here which is not by Dr. Hansen, I believe. That's the last one. 2287.

MR. CLUBOK: Perhaps just for -- the only thing that would be helpful is if these are -- this is all just one mass collection of documents that I'm not sure how they connect to any part of his testimony. If that little bit of foundation could be laid so we have some guidepost to know how they link up, that would be helpful.

THE COURT: Well, all right. Just to move this along, you are not introducing these for the -- the truthfulness or the reliability of what is included within the documents; you're introducing this to support his credibility as a witness; that is, he's written articles which are peer-reviewed and these are examples of that and this is specifically what you're offering these for?

MR. PAWA: Yes.

THE COURT: Is that right?

MR. PAWA: Yes. And there's a few that are not by him that also reflect the kinds of opinions he's offering are in the peer-reviewed literature.

THE COURT: Okay. All right. So he's essentially not relying upon these; it's just that his view is consistent with other peer review journal articles.

MR. PAWA: Yes, Your Honor.

THE COURT: Is that right?

MR. PAWA: Yes, Your Honor.

THE COURT: Okay. That's for a very limited purpose. I don't -- I don't -- this is not a hearsay purpose, and it's not going to be taken for that particular point. If you attack the credibility of the witness in any particular way, then they certainly have the opportunity to introduce other articles which are consistent with his opinion, clearly; and maybe we're one or two steps ahead,

but if you impeach his credibility as a witness, then they have certainly the right -- or his opinion as a witness, then they certainly have the right to introduce articles which are consistent, but that's -- you know, that's if you're going to do that.

MR. CLUBOK: Well, right. I think we're -- first of all, I think these articles may or may not be relevant to the Daubert challenge, so I can see them being cited in connection with whatever procedure the Court permits in terms of addressing the Daubert issues, and I certainly --

THE COURT: Can I just cite that? If you're going to raise a Daubert issue in regard to any particular witness or you're going to raise a Daubert issue in regard to any witness, then during the course of the trial, during the course of your cross-examination, you establish the point that you want to make in regard to that particular portion of the testimony that you're contesting, and then there will be supplemental briefing at the end and then the Court will have to make a separate ruling, whether it's incorporated within the final ruling or a separate ruling on the Daubert issue. If you're going to call it a Daubert issue.

If you're going to call it just it's not as much reliability, don't give it much weight, then, you know, I wouldn't go through that analysis. But if you're going to raise an issue to exclude a portion of the testimony, then

you have to establish that on cross-examination or on your own witness and then supplement it with briefings after the evidence has been closed, and then I have to make a separate ruling. That's the most logical way of going forward.

Now, any disagreement with that process?

MR. PAWA: No, Your Honor.

MR. CLUBOK: That's fine. That's perfect.

MR. PAWA: I'm also reminded I need to move into evidence the demonstratives.

THE COURT: All right. Okay.

MR. PAWA: Which we do now.

MR. CLUBOK: But maybe Your Honor ruled and I missed it. On these articles --

THE COURT: I haven't ruled on that yet.

MR. CLUBOK: Okay. I didn't know if --

THE COURT: You didn't miss it.

MR. CLUBOK: Okay. Thank you, Your Honor.

THE COURT: Because it didn't happen.

MR. CLUBOK: Okay.

THE COURT: So --

MR. CLUBOK: Are we still discussing that or --

THE COURT: We are discussing that, but Mr. Pawa wanted to make sure that he didn't forget before he went back to his seat that he had -- that he had not introduced the demonstratives.

MR. CLUBOK: Okay. Which should I address?

THE COURT: The first one.

MR. CLUBOK: Okay.

THE COURT: That is, these -- these articles.

MR. CLUBOK: Okay. We would object -- I certainly object to the articles just being introduced in a collection en masse without any foundation linking up these articles to any specific thing that Dr. Hansen said. It puts the burden on us to spend I'm not sure how much time trying to parse through what relevance these articles have.

If what Mr. Pawa and Dr. Hansen are saying is here's a collection of articles, you agree with every single word in all of these articles and these are being offered to show that these peer-reviewed articles are consistent with the opinions you've offered, purely for Daubert purposes but not for the truth of the matter asserted, I think that covers our range of issues with this.

THE COURT: Okay. All right. Well, to short-circuit this issue, Dr. Hansen testified at the very beginning that he wrote peer review articles, and to the extent that 2281, 2282, 2283, 2284, 2 -- I think that's it, for peer review articles that he wrote, to the extent that that supports his testimony, it's relevant for that purpose. It's not relevant for what he said here, but it's relevant for that particular purpose.

Now, I'm going to reserve judgment in regard to the other exhibits, because if there's some question about the reliability of his testimony, you then are proffering these peer review articles as corroborative of his opinions; then they become relevant. But right now they're not technically relevant. Or if there's a Daubert issue, then obviously these become relevant, as well.

So I'll reserve judgment on 2287, 2290, 2291, and 2292. And in regard to the -- the series of demonstratives, technically I've already reviewed them, so technically they're already into evidence, but is there any objection to these particular exhibits?

MR. CLUBOK: Yes, Your Honor. If we could have just -- could you put up Slide 35. I want to follow Your Honor's instructions.

I don't have objections to most of the slides as reflective of Dr. Hansen's testimony, but with respect to Slide 35, if that could be put back up. His summary. Maybe it's Slide 36. The one that had his two opinions, summaries at the end.

THE COURT: You're asking -- you're objecting to the summary. Is there still time --

MR. CLUBOK: Here. This, Your Honor. Just to clarify our Daubert issue so it's crystal clear, the second bullet point, that's part of our Daubert challenge, the idea

that essentially it's part of Dr. Hansen's abrupt climate change theory, which we do not think is generally accepted in the scientific community and would pass the standard of Daubert.

Second -- the first slide, however, the first opinion is one that Dr. Hansen has not even been qualified in any way to address whether or not the alternative scenario, which involves massive change in technology -- I'm not sure even if this alternative scenario is limited to AB 1493 and Dr. Hansen is trying to say that he's saying it's feasible, which of course is a subject for technical experts and not something that Dr. Hansen could possibly opine on, or if that opinion is supposed to mean that his entire alternative scenario, of which AB 1493 or the like is one part, it is a whole new, entirely different kind of opinion.

THE COURT: Okay. After every expert witness that have been presented by the plaintiff and the defendant, there has been at the very end a summary, and technically it is just a summary of what the person did, and I would suppose that each party is presenting that just as a capsuling of the argument that is made and for no relevant evidentiary purpose. In other words, I don't turn to this and say this particular piece of scientific analysis upon which I can rely. It is merely just a tool that the sides are being -- are using, and I, quite frankly, could have

said at the very beginning, you know, you don't need to put in the tool. I mean, I've heard it. But it seems to me that it's -- you know, it's okay for the parties to put in this little summarizing tool. That's what basically this is.

I -- I appreciate the fact that in addition to a summary tool there is a little bit beyond that in this particular document, "action needed now." Perhaps that's an argument of some sort, but I really don't think I'm going to be relying upon this. Anyway --

MR. CLUBOK: Your Honor, I'm sorry. It's my fault I'm not being clear. I don't have an issue with the argument. I don't have an issue with the summary of -- slides that summarize his opinion. That's not the concern at all.

There's two different opinions that are basically reflected here. The second one is a summary of the opinion for which we're reserving our Daubert challenge, and pursuant to the Court's instructions I'm trying to make that clear. The first bullet point, though, is something that I did not jump up and object to because it was at the very end, it was one of the last things that Dr. Hansen said, and I wanted to be polite and to not jump up right in the middle of his sentence; but I want to make it clear, Dr. Hansen slipped in an argument that said essentially it's

technologically feasible -- or one might take it that way, and that's the only thing -- just to preserve the record and make it crystal clear, we do not think that Dr. Hansen in any way has been qualified to testify about the feasibility.

THE COURT: I agree that he is not qualified as an expert to talk about the feasibility of the various technologies. I mean, to make this relevant to this argument, though, is different. He's talking about his alternative scenario in general. He's not talking about the technological issues. I agree that when he talked about the technological issues of car manufacturers, that that was beyond his expertise. I don't think he would recognize -- I think he recognizes he's not an expert in turbocharging and the effects upon fuel economy standards.

MR. PAWA: They can't depose Duleep again.

THE COURT: Okay. And I appreciate -- your argument is reserved, obviously, on that particular issue.

MR. CLUBOK: Thank you, Your Honor.

THE COURT: But as far as this individual document which is talking about the alternative scenario that he described, in regard to climate change anyway, it is admissible.

In regard to the other demonstratives, any objection?

MR. CLUBOK: I'm sorry, Your Honor. No. The rest

of them as reflective of his testimony, we have no objection.

THE COURT: Okay. All right. Thank you, Mr. Pawa.

I think we go to cross-examination.

(Defendant's Exhibits 2281-2287 and 2292 were received in evidence.)

MR. CLUBOK: Thank you, Your Honor.

CROSS-EXAMINATION

BY MR. CLUBOK:

Q Good afternoon, Dr. Hansen. Dr. Hansen, I try my best not to interrupt -- or I kept my interruptions at a minimum while you were providing that information, and I'm just going to ask at the outset -- I think you've probably gotten the sense that all the parties are at this point pressed for time, and if I ask you a question and there's any way that you can just answer it yes or no, even if you want to explain the reason, if you would do me the favor of saving the explanation for Mr. Pawa to the extent that he wants to elicit the explanation. Is that acceptable?

A Sure.

Q Thank you very much. Now, Dr. Hansen, is it -- is it your understanding that most, if not all, of the general circulation models or the global climate models or the GCMs that you were speaking about, is it your understanding that

most, if not all, project that with a climate warming, snowfall over Antarctica as a whole will increase?
A Yes.
Q Thank you.
A I think all of them would.
Q Thank you. And in fact, there are some projections by experts which say that Antarctica is going to gain ice even if there's global warming; isn't that true?
A It's true, but not with credible models.
Q Okay. And again, Dr. Hansen, if -- if you can answer my questions yes or no, even if you then want to explain the answer, I would really appreciate it if you'd hold off on that for Mr. Pawa, okay?
MR. PAWA: Your Honor, we object to the instruction. To the extent he needs to clarify to have an intelligent answer, he should be able to do so, even if it's succinctly.
THE COURT: Well, the general rule is if it calls for a yes-or-no answer in a leading cross-examination question, you should respond yes or no; or if you can't answer that completely and honestly, then you can say, "I can't answer that." In which case there can be further exploration by either counsel.
MR. CLUBOK: Thank you, Your Honor.
THE WITNESS: What if the -- could I ask for

clarification?

THE COURT: Yes. Sure.

THE WITNESS: What if the answer yes or no leads to a very misleading impression?

THE COURT: Well --

THE WITNESS: A good example would be just the prior question, because the models that he refers to do not include the physics relevant to ice sheet disintegration and sea level; so it's really an irrelevant question that he asked, but when I say yes, it sounds like I'm agreeing with what he says -- what he's implying.

THE COURT: Then I would guess that the answer to that kind of question is that you can't respond in a yes-or-no way --

THE WITNESS: Okay.

THE COURT: -- without further explanation.

THE WITNESS: Yeah.

BY MR. CLUBOK:

Q That's a truthful answer, you can't respond yes or no to the question.

Is there some projections by some experts that Antarctica is going to gain ice in a global warming? Can you answer that truthfully yes or no?

A By "some experts," I could answer that and say yes, there probably are some experts.

Q Thank you. And that would cause either a decrease in the sea level or at least a slowing of the rate of increase in the sea level, correct?
A Again, I -- the -- I can -- I can answer that. It would -- directly, but it would be misleading; but if in fact someone claimed that when the world gets warmer ice sheets get bigger, then, sure, sea level would go down. It's an implausible scenario, but --
MR. CLUBOK: Can I play Clip 15, please? Actually, can I play Clip 14 and then Clip 15.
[Video clip of deposition of James E. Hansen, Ph.D., played as follows:
Q. Is there some projections --]
MR. CLUBOK: Page 211, Line 14 to --
(Interruption by the reporter.)
MR. PAWA: Is there a question pending with this clip?
THE COURT: There is not a question pending.
MR. CLUBOK: I'm going to use this to impeach Dr. Hansen's claim that he can't just give a yes-or-no answer truthfully under oath. I have no doubt that there's many explanations that Mr. Pawa could elicit. I have no doubt that he is very skilled at arguing relevance. I have no doubt that he could do all kinds of things. I'm hopeful that if he's capable of, under oath, answering a question

the way he answered it in a deposition, that I could just get that answer; and if he wants to explain further, I presume Mr. Pawa will elicit it.

So could we play Clips 14 and 15, please.

[Video clip of deposition of James E. Hansen, Ph.D., played as follows:

Q. Is there some projections by some experts that Antarctica is going to gain ice in a global warming?

A. Yes.

Q. And that would cause either a decrease in the sea level or at least a slowing of the rate of increase in the sea level?

A. Right.

Q. Correct?

A. Right, right.]

BY MR. CLUBOK:

Q Dr. Hansen, to the extent that you are capable of answering a question under oath in your deposition without at that point explaining further, could you please to that extent just answer yes or no while I ask questions and any explanations --

A Well, I already -- I already answered that.

Q Okay.

A And in fact, I've written a paper in which I discuss the model which has the ice sheets growing as the Earth gets

warmer, and, you know, it -- and I point out the flaws in the model for why it gets that answer.

Q Dr. Hansen, you are familiar -- we talk about the Intergovernmental Panel on Climate Change, or the IPCC, correct?

A Could you repeat that?

Q You're familiar with the Intergovernmental --

A Sure. Yes, I am.

Q -- Panel on Climate Change?

A Yes, of course.

Q Or the IPCC?

A Yes.

Q And the IPCC is a group -- basically is a group of scientists who work together under the United Nations to provide the best summary of the status of our knowledge regarding climate change, correct?

A Yes. You could say that, yes.

Q Thank you. And the IPCC basically takes all the different views and -- first of all, they report the consensus mainstream opinion, correct?

A No.

Q Okay.

A I just have a letter --

Q That's okay. That's okay, Dr. Hansen. That's all the answer I need is yes or no.

MR. CLUBOK: Could I play Clip 17, please.

[Video clip of deposition of James E. Hansen, Ph.D., played as follows:

Q. And what they do is they take all of these different views and they report the consensus mainstream position, correct?

MR PAWA: Objection.

A. Yeah.]

MR. BOOKBINDER: I'm sorry. Could we get page and line numbers?

MR. CLUBOK: Yes, but could I have one attorney at a time objecting if at all possible?

THE COURT: Let's move this along. You want to give them the page and line number?

MR. CLUBOK: I'm sorry. Page 119, 4 to 7.

BY MR. CLUBOK:

Q Okay. I asked that question and you gave that answer at the deposition; is that correct?

A What answer did I give?

Q "Yeah."

A Yeah. And could I explain why I said something different?

Q Well, Mr. Pawa will give you the opportunity to explain with a question.

MR. CLUBOK: Thank you.

THE COURT: Okay.

Q And, sir, you are familiar with the 2001 IPCC report regarding the prediction for change in sea level by 2100, correct?

A Yes.

Q And in addition -- and by the way, the IPCC reported a range of predictions, not just the consensus mainstream or best estimate but entire range of predictions; isn't that true?

A Yes.

Q And the range of predictions reported in 2001 on the IPCC for predicting change in sea level by 2100 was at that time a maximum of 88 centimeters; isn't that true?

A Yes.

Q And there's a more recent, though, 2007 IPCC report, correct?

A Yes.

Q And that's the one you were saying is not out yet but you have a sense of what they're going to say?

A Well, in fact, the relevant thing on sea level is already out, I believe.

Q Okay. And so you're familiar with the relevant position in the 2007 IPCC report on sea level, and isn't that true that now the range of predicted centimeter increase in the sea level by the consensus mainstream

position is 59 centimeters by the year 2100, correct?
A No. That's very misleading, because now they explicitly say that that does not include the contribution from the ice sheets, which is what we've been talking about today.
Q Okay. But what they do say is taking that out of the equation, the maximum predicted change in sea level -- actually, the predicted change ranges from 18 centimeters to 59 centimeters taking out the ice sheet melting issue --
A Right.
Q -- correct?
A Right. Right.
Q And in fact, in 2001, by the way, what was the scenario A1B prediction best estimate for global temperature change by 2100? Are you familiar with that?
A I don't know exactly.
Q I'm going to hand you what's been marked as Plaintiff's Exhibit 1237 - it's the Summary for Policymakers from the 2001 IPCC report - and ask if you recognize that document, sir, Plaintiff's Exhibit 1237.
A Yeah, I've seen this before.
Q Okay. And you are familiar that in 2001, if I can refer you to -- I'm sorry. If I can refer you to Page 12 -- I'm sorry, Page 14 of 1237, isn't it true that under scenario A1B the consensus best estimate was an increase in

global temperature of 3.0 degrees?
A Yeah, I think that's right.
Q Okay. And you say you've seen the 2007 IPCC prediction that reflects newer information. Isn't it true that that same -- the same scenario, A1B, with respect to the prediction for temperature increase, global temperature increase by 2100, has decreased since the prediction from 2001?
A I -- I don't know that, but I'd be willing to take your word for it. I'm sure that's available.
Q Oh, okay. You haven't looked into that before testifying here today?
A No.
Q Okay. I'm going to hand you what's been marked as Plaintiff's Exhibit 1197. This would be the Summary for Policymakers 2007, and I believe this report just came out maybe within the last few days; is that correct?
A I -- again, I'm not certain when it came out.
Q Okay. But a draft has been circulating for months, correct?
A Yeah. That's right.
Q And you had reviewed that before you came to testify here today, correct?
A No.
Q Oh. Okay. Well, then, does it surprise you to learn

that the predictions now for scenario A1B, the mainstream consensus opinion, has decreased -- the projected increase in global warming was lower now than it was in 2001; does that surprise you?

A No, it wouldn't surprise me that it changes one direction or the other.

Q Okay. And in fact, it changed pretty significantly, correct?

A I don't know. Which graph is it?

Q Well, that's okay. We'll maybe refer to that later.

Now, sir, with respect to the glacial issue, the ice sheet melting, isn't it true, sir, that you can't point to a --

A Wait. I think we should look at -- you asked about A1B. It's hard to see because these are in black and white and all the curves are the same, but it looks like A1B goes up to 2.8 degrees. So you're complaining about the change from 3 to 2.8?

Q Yeah.

A Oh. Okay.

Q Isn't that a significant change in the projected temperature increase?

A No. Not -- it depends on how you define "significant," but compared to -- I mean, whether 2.8 or 3 degrees, either one's a different planet than what we're on now.

Q Okay. But the difference between 2.8 and 3 is not significant, in your opinion?
A No. No.
Q Okay.
A The uncertainties are certainly larger than .2.
Q All right. Sir, with respect to -- getting back to the ice sheet melting issue, you -- you're not a glaciologist, correct?
A No, I'm not.
Q And in fact, you are not even familiar with the models that have -- the results of the models that have attempted to model behavior of Antarctica in the 21st century, correct?
A There are no models that contain the relevant physics that you could use for that problem.
Q Okay. But there have been some models, and you're not familiar with the results of the models that exist today, correct?
A I'm not familiar with great detail about them. I'm familiar with the results in a qualitative, semiquantitative way.
Q Okay. Fair to say you're just not really familiar with the results of the models; is that fair?
A I'm familiar to the extent that's relevant to this discussion.

MR. CLUBOK: Okay. Can we play Clip No. 1, please. I'm sorry, Page 73, Line 22.

[Video clip of deposition of James E. Hansen, Ph.D., played as follows:

Q. Are you familiar with whether or not scientists have attempted to model the behavior of Antarctica in the 21st century?

A. I'm familiar -- I -- I'm sure that there are scientists who have attempted to do that.

Q. Okay.

A. I'm not familiar with the results of their models.

Q. Okay.]

BY MR. CLUBOK:

Q All right, sir. By the way, the IPCC did not ask you to contribute your views on projected changes in sea level in the next hundred years for their most recent report; is that correct?

A I don't know. I mean, I was asked to do a number of things for IPCC, but I did not get involved in the IPCC report-writing.

Q Well, in fact, you would have been very surprised if they would have asked you with respect to sea level changes because you've not done -- you've not provided any model simulations that relate to that, correct?

A That's right.

Q Okay. And in fact, you don't know how to calculate ice sheet disintegration with the current knowledge, correct?
A You know, actually, let's go back to that previous question, because actually, I was the first one to point out in late 1970s the effect of thermal expansion of the ocean on causing sea level rise, and that's the one thing they did include, so actually my background is relevant to the question of sea level rise. The part that they addressed.
Q You're saying you would have been very surprised if they had asked you?
A Oh, I would not have been very surprised, because --
Q That's okay.

MR. CLUBOK: Let's play Clip 2, if we can. This is Page 111, Line 11.

[Video clip of deposition of James E. Hansen, Ph.D., played as follows:

Q. And you don't know whether you're a contributing author with respect to specifically the chapter dealing on sea level increase?

A. I think in that case I would be very surprised if I were because I have not -- that -- the model simulations that I provided to them did not include sea level change because I -- I don't know how to calculate ice sheet disintegration with our current -- current knowledge.]

THE WITNESS: Now, what I just referred to was the

other part of the problem, the thermal expansion, which as I mentioned, I was the first one to do it.

BY MR. CLUBOK:

Q All right.

A So there are two different parts to this problem.

Q Okay. But regardless, you're not listed as an author -- you're not --

A Right.

Q -- a contributing author --

A Right.

Q -- to the 2007 report on sea level change, true?

A Right. That's right.

Q All right. And in fact, now, you say, though, that the greatest rate of change in sea level during the period from the last ice age to the present interglacial occurred about 14,000 years ago. Correct?

A Yes.

Q And that -- that was near the end of a major continental glaciation, wasn't it?

A The glaciation, yes.

Q Thank you. And basically what that means is the world was covered in ice, there was glaciers everywhere, in particular North America, like the United States and Canada, I think you mentioned, in Europe, I think, too, all covered in ice. At some point much of that ice melted, which has

led to what we now call an interglaciation period where there's no ice in North America, at least, correct? Basically in laymen's terms did I get that right?

A Yeah. That's fine.

Q Okay. And that -- that rate of sea level that you have said that existed back then, you said that it would, in your opinion, about 20 meters per -- over a span of 400 years of sea level rise?

A Yeah.

Q And that was during the process of the disintegration of Laurentide ice sheet, correct?

A Yes.

Q That was the ice sheet that used to cover all of North America, correct?

A No. Not all of North America. It covered Canada and reached into some northern parts of the United States.

Q Fair enough. But the planet at the time looked very different with the ice sheets over North America and northern Europe, correct?

A Yes.

Q Now, sir, we are now in an interglacial period today, correct?

A Right.

Q And is there any literature -- any peer-reviewed literature that you're aware of that reports a change in sea

level during interglacial periods of approximately 5 meters over a hundred-year period?
A I don't think so. There's not -- as far as --
Q Okay. Thank you.
A -- I'm aware, there is not.
Q How about any literature that you're aware of that reports a change in sea level during an interglacial period of as much as 4 meters over a hundred-year period?
A There are papers -- I think you had asked me about this before, and I referred you to one by Thompson and Goldstein which found -- which estimated changes of several meters during what they called suborbital periods, including both glacial and interglacial times. So I don't -- they don't -- they cannot put an exact -- it's very hard -- as you recall in my testimony, when we talk -- we're not even sure if 5 meters was the sea level rise during the interglacials or whether it was 3 meters. So if you ask me five or is it four, well, I can't distinguish between those.
Q Okay. I understand you can't, sir. I'm asking if any of that peer-reviewed literature you've read -- I think you've listed thousands of articles as references. I'm just wondering, Are you familiar with any peer-reviewed literature that reports a change in sea level during the interglacial period of as much as 4 meters over a hundred-year period? Any -- any literature that reports

that?
A Well, I can't quote any literature here, no.
Q Okay. And you're not -- and I asked you this question months and months ago during your deposition, correct?
A You asked questions along that line, yeah.
Q In fact, this precise question, right?
A That could be.
Q Okay.
A I don't remember.
Q And that was actually at your first deposition. Then there was a second deposition where you mentioned that Thompson paper that you've just raised today to Ms. Bennett, I think, correct?
A Um-hum.
Q But other than that Thompson paper, you found no literature that related to this subject, correct?
A I didn't go back and pursue that, but I've actually received comments that -- glaciologists who basically are saying they agree with me.
Q Okay. And we'll get to that, but I wanted to speak about the literature that we can actually read in a peer-reviewed journal, and we'll get to the glaciologists that you've spoken to in a minute.
How about any literature that reports a change in sea level during interglacial period as much as 3 meters over a

hundred-year period that you're aware of?
A I -- yeah. I would have to -- I did not -- after our previous discussion, I did not go back and try to find a paper, so I cannot quote any on the spot, and I -- my answer to that would be there probably is, but I can't -- I can't give you them today.
Q Well, your honest answer is as you sit here today you don't know; isn't that true?
A Right. I -- yeah. I don't know.
Q Okay.
A I expect there are, but I don't know for sure.
Q All right. And, sir, with respect to peer-reviewed literature that reports a change in sea level during interglacial period of as much as 2 meters over a hundred-year period?
A You see, and the reason is we don't have the ability to measure that.
Q I understand. We'll get to the reasons in a minute. But you're just not aware of any, correct?
A No, I'm not aware of any.
Q And you're not ware of any that reports one meter of increased sea level over a period of a hundred years, correct?
A I'm not aware of any that report specific measurements of any -- of any size within interglacial period. As I say,

I expect they exist, but I would have to go back and look at the literature.

Q Well, you actually referred us to the Thompson paper, which is the paper you just mentioned now, the paper you told Ms. Bennett about. Are you familiar with how much increase in sea level the Thompson paper reported on a -- over a hundred-year period?

A Over a hundred -- over a hundred-year period?

Q Yeah.

A Again, I -- no, I don't know the exact numbers from his paper.

Q Okay. Would it surprise you that it was -- well, fair enough. If you don't know, then you don't know.

Now, sir, with respect to glaciologists that you've talked to - now we're outside of the world of peer-reviewed journals but just folks you might have spoken to - are one of those glaciologists Richard Alley?

A Yes.

Q He's one of the top experts in the field of ice sheet dynamics; isn't that true?

A Yes.

Q And you believe that Richard Alley agrees with your theory on ice sheet disintegration?

A Well, I don't think I have a theory on ice sheet disintegration. I don't know what you mean by that.

Q Well, you're predicting, sir -- this -- most of the abrupt climate change that you're predicting is as a result of 25 meters of sea level increase or some very large amount caused by ice sheets essentially disintegrating in either Greenland or Antarctica; again, in laymen's terms is that a fair summary?

A Yeah.

Q Okay. And do you believe that Richard Alley -- and you believe, by the way, that if we don't do something in the next ten years, we could pass a point of no return where that's just going to keep happening, the ice sheet's going to keep melting and it's too late to do anything about it?

A Yeah. I think that's a real possibility.

Q A real possibility. But it's certainly not the consensus opinion of the mainstream scientific community, is it?

A I -- my assessment of the mainstream opinion is now that they do agree that we would expect more than a meter sea level rise; and in fact, since our last discussion I know at least three of them who now will say this publicly. They're the leaders in the field.

Q Okay. But, sir, I'm not -- you switched to more than a meter of sea level rise. I want to focus on the amount of sea level rise that would cause this massive abrupt climate change or the sea level rising 25 meters and the serious

problems that if we don't address, in your opinion, in the next 10 to 15 years it's going to have that effect.
A Um-hum.
Q Sticking with that subject, that theory has not gained general acceptance in the scientific community; isn't that fair?
A Well, I don't -- they're not -- they haven't given an opinion on that, to my knowledge.
Q Okay. So you would agree with me that at least -- maybe you'll convince them, but at this point that theory has not gained general acceptance in the relevant scientific community, correct?
A Yes. I guess that's right.
Q All right. And in fact, Dr. Alley just testified before Congress February 8th, 2007, and directly contradicted that theory, didn't he?
A Not to my knowledge.
Q Well, are you aware of what Dr. Alley said to Congress on February 8, 2007, on this subject?
A I saw part of his testimony, but not the entire thing.
Q Isn't it true that Dr. Alley says that it is only possible that if a certain temperature is reached over decades and then if it's sustained, ice sheet could be lost over centuries to millennia; i.e., hundreds of years to a thousand years? Isn't that essentially what Dr. Alley said?

A Yeah. And that's not -- that's not all that inconsistent with what I've said, either.
Q Okay. Dr. Alley certainly didn't suggest that something immediate has to be done in the next 10 to 30 years or we've passed some tipping point where this is on an irreversible decline, correct?
A I don't -- I -- probably he didn't say that, but I suspect he may agree with it. I don't know what he said, though.
Q Well, actually, don't you think that he said that there's additional uncertainty as to whether or not the melting will either slow down or speed up; there's just a big uncertainty out there? Isn't that basically what he said?
A That -- I don't know if he said that.
Q Okay.
MR. CLUBOK: Can we play Clip No. 3, please. There's no page number. This is congressional testimony, February 8th, 2007, of Richard Alley.
I'm sorry. Clip 1. Clip 1. I apologize. Clip 1.
MR. PAWA: Your Honor, I just want to clarify. This is impeachment only, not for the truth of the matter?
MR. CLUBOK: That is exactly right. It is for impeachment only.

Video Clip 1 if you have it.

Maybe it won't be for anything.

[Video clip of testimony of Richard Alley played as follows:

"Uncertainty that you just don't know whether these changes in the spreading of that giant pile in Antarctica or that giant pile in Greenland will slow down, whether they will stay constant, whether they will speed up."]

BY MR. CLUBOK:

Q Sir, in fact, you aren't familiar with any model that agrees with any prediction that a 2-degree increase in temperature by the year 2100 would have anything like the effect you're suggesting; isn't that true?

A There -- there's -- it's well agreed there are no models to address this problem, so of course not.

Q Okay. Now, sir -- and, of course -- well, let's go to the impact of the regulation and what you did testify about.

MR. CLUBOK: Can I get Slide 34 on the screen again, I believe?

THE COURT: Are you going to take Dr. Alley off the screen?

MR. CLUBOK: He loves the camera, sir. And the camera loves him, so I was giving him the most chance possible.

Q The -- this was your -- this is one of the slides you

showed to show the effect of taking action with respect to U.S. auto and light truck CO2 emissions, correct?
A Yes.
Q And I think you said this would be a significant step -- or it would be a step on the path to the alternate compliance scenario you talked about?
A Yeah. Yeah.
Q And in fact, do you have a preference, sir, as to -- is there a difference between a moderate action and a strong action step? Is one a more significant step, or are they about the same?
A Well, the strong action eventually becomes -- has more impact.
Q Are both of them sufficient, or do you have -- is it --
A On the time scale of the next two or three decades, they're similar. They both cause the increasing slope to become a decreasing slope.
Q Okay. So not a significant difference in terms of walking down that path or going down that path --
A Not on the short term, right.
Q How about through 2100? I didn't -- any significant difference in how far we go down that path towards the alternate compliance -- or alternate scenario that you've said we need to get to?
A Sure. But, of course, you would expect that a few

decades downstream you're going to be doing additional things, but even without that, there's -- there's a difference between these.

Q Okay. And you're saying -- and which one's more important? Which one's better, in your opinion?

A Well, obviously the stronger action scenario results in less emissions.

Q Okay. Now, sir, the average variation in temperature -- surface temperature over the last 50 years has been about 3 to 4/100ths of a degree per year, correct?

A It's been 2/10ths of a degree Celsius per decade, which is 2/100ths per year; or if you want to convert it to Fahrenheit, then it's between 3 and 4/100ths per year.

Q Okay. And that's fluctuation; it just happens naturally, sort of the random variability or chaos, as you might call it? That's nothing to do with --

A The number I referred to is the trend over the last 30 years. There's been a very strong linear trend over the last 30 years, and that's not a fluctuation.

Q Right. But on a year-to-year basis --

A Oh, yeah. The year-to-year fluctuation can be larger than that in terms of a rate.

Q Okay. And, sir, with respect to the effect of the CO2 emissions savings, let's just say if just Vermont passed the regulation -- at some point it's been suggested we should

only be speaking of Vermont, we shouldn't be allowed to speak of California and any other state -- maybe New York, too. Let's throw Vermont and New York in together. Have you modeled the CO2 emission savings that would result if only Vermont and New York were to implement the AB 1493 regulation?

A I haven't modeled that. It would not be difficult to do it.

Q Okay. Well, you have that model, one of the best in the country that you've got, correct?

A Well, I wouldn't run a model with such a very small change, because then you're wasting computer time, because you do have the problem of finding a signal when compared to the natural variability of the climate.

Q Okay.

A But we know the forcings are proportional to the change in the emissions.

Q You never modeled -- let's move past Vermont and New York. Let's say that it's all 11 states that have adopted the regulation. Have you modeled that? Have you found the computer time or the time to model the total CO2 emission saving in all of the states that adopted the regulation --

A No. Because we try to do useful things.

Q Okay. How about if the entire United States adopted

the regulation, sir? If -- if all 50 states adopted and all of the CO2 emissions reductions sort of on the same scale as projected by California, New York, and Vermont, have you modeled what impact that would have on global temperature?

A I have made -- no, I have not if you just want a simple one-word answer.

Q Okay. But without even doing the model, without running your computer simulation, you would agree, wouldn't you, that even if the entire United States adopted this regulation and it was in effect until 2100, the total amount of CO2 emission savings would result in a temperature effect of no more than 1 to 4/100ths of a degree; isn't that true?

A No, I wouldn't say that. I haven't done that calculation. But a change of this percentage -- when I say this is consistent with the alternative scenario, I'm assuming that on other parts of the problem, such as building efficiencies, that similar things or even better -- in fact, the engineers agree that 50 percent improvement in building efficiencies is possible.

MR. CLUBOK: Okay. Move to strike as nonresponsive.

THE COURT: Well, objection overruled. This is included within the general area of the topic.

MR. CLUBOK: Let me just make this clear.

Q Without doing -- without even taking the computer time

to run your model, you would agree that if the entire United States adopts the AB 1493 regulations and implements them, the total CO2 emissions savings might result in 1-1/2 hundredths of a degree change by 2050; isn't that true?

A I haven't done that calculation, but in global total it would be -- if you really want to get a larger factor, you're going to have to assume that other countries are also doing it.

Q Sir, can you just answer my question, please?

A I haven't done that calculation, but --

MR. CLUBOK: Can we play Clip -- okay.

Q You haven't done the model, but you've done the back-of-the-envelope calculation to confirm that's about right; isn't that true, sir?

A That's -- that's probably the right order of magnitude.

Q Sure. And so you couldn't -- if it's really only a hundredth of a degree or if it's 2/100ths of a degree, you just haven't done the work to know, correct?

A Right. I have not done calculations where I put in only one state or small number of states.

Q Okay. Now, sir, on Slide 34, you show what appears to be a pretty big delta between what would happen with no action versus what happens with moderate action. You see that green line I've drawn on the screen?

A Um-hum. Yes.

Q That makes it look like there's going to be a real change, and that's the moderate action. With the strong action it looks like it's an even bigger change; is that correct?

A Yeah.

Q Now can we go back to Slide 14. Slide 14 was the slide that showed temperature projected under these different IPCC scenarios as compared with, I think, what you call the alternative scenario, the place that you think we need to be. Correct?

A Yeah.

Q And essentially A1B, that scenario that's the mainstream consensus view of what's going to happen by 2100, you say we need to go from there down to here. Is that basically right? I've drawn a line just on the Elmo.

A Yeah.

Q Sort of showing -- it's about the same -- same magnitude, basically, really, as that change in CO2, right, that we're going to achieve by the AB 1493 regulations; isn't that right?

A Yeah.

Q Yeah. But at least that's what it appears on a screen like this when we compare those two slides. In fact, sir, if I clear this off - you could use your finger to draw it, if you would - can you draw on the slide starting with A1B,

if you could just graphically draw -- the way it works is a pretty cool thing. You can stick your finger on the screen, and if you hold it down, it draws a line. So what I'm going to ask you to do is put your finger on A1B and assume that AB 1493 is enacted and just draw the line down showing -- as you said, it was --

A Nothing else is done in the rest of the world?

Q Yeah. Nothing else is done in the rest of the world.

A Then it would be a very small change.

Q Well, however small it is, put your finger on and, if you would, please, draw the amount.

A I think you mentioned a couple hundredths of a degree. But I haven't done that exact calculation, but --

Q There would be no possible way with your finger you could indicate that, correct?

A It would be smaller than the -- than the unforced variability of the system, that's true.

Q You'd need a microscope to see the impact put into that context; isn't that true, sir?

A Yeah. Put into that context, yes.

MR. CLUBOK: That's all I have.

THE COURT: Okay. Mr. Pawa, any redirect?

MR. PAWA: Yes.

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REDIRECT EXAMINATION

BY MR. PAWA:

Q Dr. Hansen, do you have the exhibits that I gave you before, including Number 2287?

A Yes.

Q What is the title, please, on 2287, and who is the author?

A "Paleoclimatic Evidence For Future Ice-Sheet Instability and Rapid Sea-Level Rise," and the authors are Jonathan Overpeck, Otto-Bliesner, Miller, Muhs, Alley, and Kiehl.

Q Which Alley is that?

A That's Richard Alley.

Q Would you read the first paragraph, the abstract of this scientific article, please?

A "Millions of people and their" --

Q I'm sorry. The abstract.

A Oh, the abstract. "Sea-level rise from melting of polar ice sheets is one of the largest potential threats of future climate change. Polar warming by the year 2100 may reach levels similar to those -- to those of 130,000 years ago to 127,000 years ago that were associated with sea levels several meters above modern levels; both the Greenland Ice Sheet and portions of the Antarctic Ice Sheet may be vulnerable. The record of past ice-sheet melting

indicates that the rate of future melting and related sea-level rise could be faster than widely thought."

Q Could you read the last sentence of the article in addition, please, Dr. Hansen.

A "Antarctic" -- oh, wait. It's a long sentence. "Moreover, a threshold triggering many meters of sea-level rise could be crossed well before the end of this century, particularly given that high levels of anthropogenic soot may hasten future ice-sheet melting, the Antarctic could warm much more than 129,000 years ago, and future warming will continue for decades and persist for centuries even after the forcing is stabilized."

Q What's the date of the article, please?

A March 24th, 2006.

Q And what publication?

A In Science.

Q Is Science magazine a peer-reviewed journal?

A Yes, it is.

Q Who is Jonathan Overpeck, if you know?

A He's at the Institute for the Study of Planet Earth and University of Arizona.

Q Is he a respected scientist?

A Yes, he is.

Q Is he part of the IPCC; do you know?

A I believe he is.

Q Does this article corroborate the views you've expressed today with respect to the risks of rapid sea level rise?
A I think it is consistent with them, and this is a reasonable representation of what the community is -- is thinking.
Q Does this corroborate your view with respect to the paleoclimate evidence of past sea level changes?
A Yes. Again, it's very consistent. Overpeck is an expert on paleoclimate evidence.
Q Would you take a look, please, at Exhibit 2292. Do you have that in front of you?
A Yes, I do.
Q What's the title of that article?
A "Measurements of Time-Variable Gravity Show Mass Loss in Antarctica."
Q And is this published in a peer-reviewed journal?
A Yes. It's in Science, also.
MR. CLUBOK: Your Honor, I'm going to object to any more leading questions. It's one thing if Mr. Pawa says to Dr. Hansen, Tell us what these articles mean. It's another thing if Mr. Pawa just leads Mr. Hansen -- or Dr. Hansen, I'm sorry, through these various statements and asks him to read them into the record. That's leading, and on direct or redirect it really should not be permitted.

THE COURT: Well, first of all, if you asked general questions, that would be helpful; but then as -- then once you've established the general question, then you can certainly ask him to refer to particular parts of the statement. But technically plaintiff is right. You're supposed to start with a general observation.

Q Are you familiar with this article?

A Yes, I am.

Q What is the significance, if any, of this article with respect to Antarctica?

A It shows that contrary to what had been believed a few years ago, Antarctica is actually losing mass at a significant rate despite the fact that snowfall rate is increasing in the -- in the center of the ice sheet.

Q And these measurements come from what kind of data-gathering?

A It's from the GRACE satellite, which is the gravity satellite. It measures the gravity field of the Earth with great precision.

Q Is it scientifically accepted -- is there a scientifically accepted view as to whether or not Antarctica in fact is gaining a net mass of ice or losing?

A This is a very active field, and these measurements are now only since 2002, and they're still improving the orbits of the satellite, but it's now -- there's no disagreement.

There are different analyses of this same satellite's data, but they all show Antarctica losing mass over these recent years.

Q What response, if any, do you have to the -- some experts who might say that in the future Antarctica will gain ice mass as a result of the warming temperatures?

A I think that that's implausible, because as I showed earlier in my testimony, there's just a very strong positive correlation. When the Earth gets warmer, ice melts and sea level goes up. It's implausible to think that it would work the opposite way in the future.

Q You heard Mr. Clubok talk to you about the IPCC's 2007 report, correct?

A Yes.

Q And you recall he indicated that at the bottom end of the sea level rise projections, the projections in IPCC suggested 18 centimeters in the next hundred years; do you recall that?

A Yeah.

Q What's sea level rise going at? What rate is it going at right now as we sit here today in centimeters per century?

A Well, the most recent refereed result is about 3.4 centimeters per second. There's a paper submitted for publication which is even higher.

Q I'm sorry. It's centimeters per second?
A Sorry. Centimeters per decade.
Q Which is how --
A Which is 34 centimeters per year, which is about a foot and a couple inches per year -- per century.
Q Can you try that again? You might have gotten your metric mix -- I know it's a long day. If you could just try it again. You might have mixed up --
A No. I think I said -- or I said 3.4 centimeters per decade, which is 34 centimeters per century, which is something more than a foot per century is the current rate, which is double what it was a couple of decades ago.
Q All right. And how does 34 compare to 18?
A Yeah. So it's almost twice their lower limit, which is -- there are now a number of glaciologists who are -- are -- feel that the IPCC numbers are very misleading.
Q In order to have sea level rise reversed from its current rate of 34 centimeters a century to the IPCC's lower end of 18 centimeters a century, are we going to have global warming or global cooling in the next hundred years?
A There are a lot of factors which could affect sea level, so it's really -- I don't -- that's a hard question to answer. It's not plausible in my opinion that the rate of sea level rise is going to go down unless we did get less warming, if we began to get cooler temperatures, which no

one expects.
Q Thank you. The IPCC projections, are they based on the gradual component of sea level rise, or do they also include possible tipping point rapid sea level rise, as well?
A Well, they don't include anything from the ice sheets, so they do not include, obviously, the possibility of disintegration and rapid sea level rise.
Q And why is that?
A Because they felt that's too difficult. They don't have enough understanding of the physical processes. The models that had been made for ice sheets did not include ice streams, which we observe to be accelerating rapidly, and they do not include the lubrication underneath the ice sheets. So they don't have a model yet that's -- that's relevant to ice sheet disintegration. So they only addressed the part of the problem that they could.
Q If the numerical ice sheet models cannot capture those ice sheet dynamics you've described, does that mean, therefore, that the risk of -- of glacier disintegration is zero?
A No. Obviously not. I think the best guide is what's happened in the past, but it's not sufficient, because the human situation is very different. The human-driven one. Actually, the forcings of humans are larger and they're being introduced faster, so it's very difficult to assess

what the impact is going to be.

Q Mr. Clubok was asking you about 1/100th of a degree Celsius and whether or not it's important. Do you recall that?

A Yeah.

Q Could you explain in your own words why that level of a difference in temperature could be significant if that's your opinion?

A Well, my opinion is that it's important -- the most important reason that such changes in emissions are -- are important is because it will cause changes of emissions to occur other places and the effect will become bigger, but even a small change is potentially important because of the nature of the climate system and the nonlinear nature of some problems such as ice sheet disintegration. You can, in fact, have tipping points, and you don't know what is the final straw that sends you over -- causes a large change.

And the -- the same is true, incidentally, in the case of species extinctions, because there's interdependency among species. It's also a very nonlinear problem. And even if your change is only 1/1000th of the effect, even -- and even if you neglected the nonlinearities, the small change is -- when you're talking about tens of thousands of species going extinct, the small change is some number of species, and whether those are important or not, I don't

think we should -- we can easily decide that.
Q Mr. Clubok played a video clip from your deposition. I'm going to show you a piece of it that, I think in fairness, you should be -- include in your testimony today. He stopped off on Page 74 at Line 9. I'd like you to read the following question and answer, so I'm going to go ahead and give it to you from Lines 10 to 16. Can you read the first couple of -- read exactly what was played first to put it in context, because I can't remember exactly what that was.
MR. CLUBOK: What page is that?
MR. PAWA: 74. Where did you start before?
(Discussion between counsel.)
BY MR. PAWA:
Q So if you would start with 7 and finish with 16, Dr. Hansen.
A Line 7 says, "I'm not familiar with the results of their models."
And Line 9 says -- the question says, "Okay. So as you sit here today you don't know what the consensus view of the scientists who have actually endeavored to model ice in Antarctica projected over the next hundred years?
"ANSWER: That's right, because there is an understanding that there is no model that includes the critical physics for ice sheet disintegration."

Q I'd like you to read the same -- I'd like you to also read a question and answer in response to the video clip that Mr. Clubok showed you on Page 111. He left off ending at Line 19. I would like you to read lines 20 on Page 111 - you don't have it in front of you yet - through Page 112, Line 3.

So go ahead and start at Line 7 on Page 111 and continue through Page 112, Line 3.

A Okay. Line 7: "But you don't know whether or not you're a contributing author?

"I don't know whether I'll be listed as a contributing author." That was the answer.

Then "QUESTION: And you don't know whether you're a contributing author with respect to specifically the chapter dealing on sea level increase?"

Q I'm sorry.

THE COURT: I don't think that was a clip that I remember.

MR. PAWA: No, it was not. I think we're in the wrong spot.

Q I wanted you to start here, Line 7.

A That's what I did.

MR. CLUBOK: Yeah. Line 14 is where he says I'd be surprised if I was listed, so you're about to hear the rest.

A Line 14? I think that -- "I think in that case I would be very surprised if I were because I have not -- that -- the model simulations that I provided to them did not include sea level change because I don't know how to calculate ice sheet disintegration with our current knowledge.

"Okay.

"Sir, but with the current knowledge, you don't know how to calculate sea level change, correct?

"That's right. So, therefore, I use the earth's history as my guide."

I think that's the end of -- that you wanted me to read; is that right?

Q Thank you.

MR. PAWA: And that's the end of my redirect other than I want to make sure those two exhibits I had him read from are now admitted for the purpose of corroborating his testimony.

THE COURT: Okay. You want 2287 and 2292? Okay. Any objection?

MR. CLUBOK: Yes, Your Honor. Mr. Hemley, the evidence guru, is telling me that it's just improper, they shouldn't be into evidence. In any event, so --

THE COURT: You're citing Mr. Hemley?

MR. CLUBOK: I'm citing Rule 7 --

MR. PAWA: Hemley on Evidence.

MR. HEMLEY: Hemley on Evidence.

MR. CLUBOK: Your Honor, I'm citing Rule 703. Your Honor, it's hearsay. It's really not appropriate to try to introduce evidence that way for an expert.

THE COURT: Well, hearsay: You raise -- it's not that he relied upon it, but you raise the question is his opinion consistent with the scientific community, and what they're saying is that this is what the scientific community says in a peer-reviewed article.

MR. CLUBOK: Yes.

THE COURT: Which that's consistent with their position, and it's in response to that direct question.

So what does Mr. Hemley say in regard to that particular evidentiary question?

MR. HEMLEY: I can speak for myself if I may, Your Honor.

MR. CLUBOK: He's handed it to me, and I appreciate it. It says --

MR. HEMLEY: It's -- 803(18) is the hearsay exception from learned treatises, Your Honor, and to the extent that the witness relies on it, if admitted, the statements may be read into evidence but may not be received as exhibits. That's the rule as I understand it, Your Honor. You can't offer -- you can't simply offer -- I beg

your pardon, Your Honor. I know -- I don't want to -- can I go ahead and --

THE COURT: Go debate this. That's fine.

MR. HEMLEY: I don't want to argue with the Court's ruling. I really want to be respectful here.

THE COURT: Right.

MR. HEMLEY: I really do. It would be my position, Your Honor, that when a witness relies upon a learned treatise or an article -- which this witness did not do. The predicate was not laid. Getting past that --

THE COURT: Yup.

MR. HEMLEY: -- if it is shown to him, then, on cross-examination or used to corroborate his testimony in some fashion, which arguably it was, but the predicate was not laid, then if admitted, the statements may be read into evidence, which they were, but the document does not come into evidence. Otherwise we would have trial by submission of learned treatises, which is improper.

THE COURT: Okay. So under your particular theory, what you're suggesting is that they ask the follow-up question, When you rendered an opinion that the scientific community agrees with your theories and that document is, therefore, relevant because it supports his opinion that the scientific community supports his opinion, then it would be admissible?

MR. HEMLEY: I got distracted, Your Honor, but I would say --

THE COURT: You got distracted?

MR. HEMLEY: I'm sorry. I was listening to Mr. Clubok at that point. I don't think Mr. Clubok, who is going to make the decision on this, feels that this is a point that I should be debating, so I will sit down.

THE COURT: No.

MR. CLUBOK: I will just say this. Mr. Hemley is an evidence purist, and I hate to say I agree with him instead of you, Your Honor, on this issue of evidence, but the fact of the matter is with respect to the substance of the articles, if they want to have them presented to Your Honor certainly for purposes of considering the Daubert motion and determining whether Dr. Hansen's opinion -- whatever is said in those articles is consistent and meets the standard of Daubert, I have no objection to that whatsoever. So I think we're just arguing about semantics and the technical issues here.

THE COURT: Okay. So I will admit it, but I just want to make sure Mr. Hemley and I are on the same wavelengths, because we can go on at great length with this kind of thing, which I have a tendency to do.

MR. HEMLEY: Your Honor, you and I have participated in evidence seminars together. We don't always

agree.

THE COURT: Right.

MR. HEMLEY: But I have great respect for your understanding of the rules of evidence, and I will not suggest that my pronouncement is more correct.

THE COURT: But what you're precisely saying is that they did not lay the foundation in the question because they did not ask him whether when he rendered the opinion that other people in the community supported his position he did not rely upon that individual document or that individual journal, and if -- if in fact that was the case and the other side decided to stand up and say, Doctor, you read this article, did you rely upon this in making your opinion -- rendering your opinion that other scientists agreed with you and he said yes, then it's admissible.

MR. HEMLEY: Then the statement -- in that circumstance the statement could then be read into evidence, but the document under no circumstance, absent an agreement such as Mr. Clubok has just offered, could be offered. If we were staying strictly within the Federal Rules of Evidence. However, it's not a point that I wish to debate further, Your Honor.

THE COURT: All right.

MR. CLUBOK: I look forward to that seminar.

THE COURT: Absolutely. Okay. So you have

redirect?

MR. CLUBOK: Very, very briefly, Your Honor.

THE COURT: Okay.

MR. CLUBOK: First of all, I would like to offer into evidence Plaintiff's Exhibit 1238, which is the testimony of Richard -- Dr. Alley in front of the United States House of Representatives Committee on Science and Technology, February 8th, 2007.

THE COURT: You mean his entire testimony --

MR. CLUBOK: No.

THE COURT: -- or the one that was just -- that clip that was just --

MR. CLUBOK: His entire testimony, Your Honor. It's only about ten pages.

THE COURT: Okay.

MR. CLUBOK: A clip of which was a portion of.

MR. PAWA: Can I have Mr. Hemley's help on this one?

No objection, Your Honor.

MR. CLUBOK: Thank you. Your Honor's words of wisdom on that issue has spread to all of us. Very, very briefly, I just want to address this point about the path that -- consistency on path and how far we go down the path. If you can put up Slide 24, please.

Let's go back to this one. This shows, and I'm

again with my finger indicating the magnitude of change that would result in CO2 emissions in the U.S. auto and light truck CO2 category under the two different moderate actions and strong actions scenario if the regulation were adopted nationwide. Okay?

Now if we could go back to Slide 14, please. We again have on the slide the A1B, which is the mainstream consensus opinion of the IPCC best estimate as to what the global warming would be business as usual absent anything else, and we have Dr. Hansen's view that we need to get down to this alternative scenario line in order to stave off the rapid sea level rise that he's spoken of.

CROSS-EXAMINATION

BY MR. CLUBOK:

Q If you could, sir, and I know you haven't modeled this, but just back of the envelope, if you could, if you could put your finger on the start of A1B and move down the screen roughly an estimate of the total impact; in other words, how far we'd get on the path if this regulation that California and Vermont and New York have adopted were adopted worldwide, every single country on the planet adopts it, if you can show us how far, using your finger, that line would go from A1B towards that goal of the alternate scenario to avoid the climate change that you say is going to come otherwise.

THE COURT: All right, Mr. Pawa.

MR. PAWA: Just objection as asked and answered. I think this was asked before.

THE COURT: He actually asked it in the context of the United States.

MR. CLUBOK: Right.

THE COURT: And now he's talking worldwide, and the question is whether this assumes that the doctor knows about the impact worldwide --

MR. CLUBOK: That's right.

THE COURT: -- of this kind of regulation.

MR. CLUBOK: That -- that's right, Your Honor. And let's do these in steps.

Q Let's -- Dr. Hansen, you have a pretty good sense -- you have -- without -- you haven't run the model. I understand that. But you have a pretty good back-of-the-envelope sense of how far your finger would move if you did this exercise if this regulation were adopted worldwide, don't you?

A I would have to estimate. I think that vehicles are probably a third of the emissions, and you want to reduce those vehicle emissions by -- by one-third, so you're talking about a one-ninth reduction in CO2 emissions?

Q If that's your math.

A That's -- that's -- that's a pretty -- that's a pretty

significant change.
Q Okay. You haven't done the math.
A But I haven't -- I haven't done the math, and I'm not certain about the fraction of vehicles for emissions, but it's not -- it's not a negligible change by any means.
Q Well, sir, if you were to put your finger on -- we said it would be microscopic. You couldn't even draw the line if you were trying to do it U.S.-wide. If you could, sir, could you just roughly approximate, without having done the math --
A Well, if it's 10 percent -- you know, if what I just said was roughly right, if we reduced vehicle emissions by a third and if vehicles are a third of CO2 emissions, then you're talking about on the order of one-tenth of the total change.
Q Okay.
A But just as an order of magnitude as opposed to 1/100th, or a hundred percent.
Q Okay. But we're talking -- we're talking about one-tenth. Now, sir, that assumes that the gasoline-powered engine continues through 2100 in order to get that one-tenth difference between there and there; isn't that true?
A Well, I mean, this is your scenario. I would never -- this is not a realistic scenario, but I don't -- so I don't know what you're assuming to 2100.

Q Okay. Let me -- let me make it even slightly different. This regulation only affects passenger cars/ light-duty vehicles. Let's say this same AB 1493 regulation adopts worldwide. And let me be more clear because we're talking about light-duty vehicles. My colleagues reminded me of that. You still believe that it would be a one-tenth difference between business as usual and this alternative scenario that you say we need to get to?

A See, if we went back the other direction a hundred years, then you're back to horses and buggies. You just -- I don't think you can extrapolate a hundred years on this assumption. I'm not sure what relevance the current standards would have to year 2100.

You're going to have to go -- by 2100 we're going to have to have different technology for the reason that I discussed: A quarter of the CO2 stays in the air forever, and we're going to have to find different technologies on a hundred-year time scale. What we're talking about is changes that could be made on the time scale of the next few decades to get us on to a different path.

Q Okay. Let's talk about the next few decades. Let's say, then -- instead of this regulation being adopted worldwide and lasting till 2100, let's say it only lasts a few decades. Then -- and it's only light-duty vehicles. The regulation that was adopted by California. What total

difference would it make --
A Yeah.
Q -- versus --
A The practical difference is --
Q Excuse me, sir.
THE COURT: Wait a second.
Q What total difference -- not the practical difference. I don't -- I understand the policy argument. But the scientific difference that it would make based on your best scientific estimate from business as usual to the path -- or the point that you say we need to get to in order to avoid this abrupt climate change you've talked about, can you just scientifically quantify that, sir?
A Well, on this graph it would be small. Any single contribution on this graph is going to appear small.
Q Sir, if I may, I'm not talking -- I just want to be crystal clear. When you say "small," just like before, you really couldn't even move your finger because the effect would be microscopic, basically; isn't that true?
A On this scale, it would be small, yes.
Q Microscopic; isn't that true, sir?
A I don't -- I don't know if I would say "microscopic," but it would be small.
Q Yeah. And that's if the entire world were to adopt this regulation that Vermont, New York, and ten other states

have currently adopted and are trying to enforce in the next ten years, correct?

A No. Now you're back to the 10 percent change, right?

Q Oh, no, no. That's why I wanted to be sure we're clear here, sir.

A Oh, you're only going to do some of the vehicles, you mean?

Q This is what we're going to do. We're going to take the same regulation as it exists that California, Vermont -- that Mr. Duleep said is feasible, you cited the NRC study. The regulation we have and the impact that that's going to have through 2100, assume that is immediately, let's say next year, as fast as can be, adopted worldwide, so that same regulation is going to apply everywhere around the world. And assume whatever you want about whether or not gasoline-powered engines are going to be phased out.

Either tell us -- just tell us what your assumption is, that gasoline-powered engines stay till 2100 or you assume it's being phased out in 30 or 40 years. With all that assumption, if you put your finger on A1B, what's going to happen best-case -- or, I'm sorry, best estimate midway projection from the IPCC under A1B versus where you want us to be, isn't it true that if you had to use your finger to try to plot the difference, it would be a microscopic impact?

A Right. Smaller than my finger.

MR. PAWA: Hold on. Objection.

MR. CLUBOK: Thank you. That's all I have.

MR. PAWA: Objection, Your Honor. I was trying to object before he answered.

THE COURT: Okay. What's the objection?

MR. PAWA: This was a very long speech in which the question was vague, ambiguous, and multiply compound. It was not a proper question. Objection to the form.

THE COURT: I was confused about whether you limit it to passenger cars and light-duty trucks or whether you also had the two light-duty trucks 2 and light-duty trucks 2 and --

MR. CLUBOK: Let me -- I'll clear that up for Your Honor, because I want to be crystal clear here.

Q Let's assume that it's the regulation that's right now 11 states. Let's assume -- and so it covers passenger cars --

THE COURT: Wait. It's 12 states.

MR. CLUBOK: I'm sorry, Your Honor. Right now it's 12 states.

Q Passenger cars and light-duty vehicles, the regulation that exists, that is adopted worldwide, basically AB 1493 is taken by every single state. The effect on this path that we need to get to, according to your opinion, would be

microscopic; isn't that true?
A No, I never used the word microscopic. I said it would be small compared to the total change that we need.
Q Okay. I'm sorry. If I was trying to use my finger to graphically show the change, that --
A It's much smaller than your finger on this graph, yes.
MR. CLUBOK: Okay. Thank you. No further questions.
THE COURT: Okay. All right. Thank you, Dr. Hansen.
(The witness was excused.)
THE COURT: All right. Now, tomorrow Dr. Rock is testifying and who else?
MR. PAWA: Dr. Berck.
THE COURT: I'm sorry?
MR. PAWA: Dr. Berck will follow Dr. Rock.
THE COURT: Okay. I thought -- I thought --
MR. PAWA: Oh, I apologize. Dr. Christy. I should know that. We'll work it out whether it will be Rock, Christy or Christy, Rock. I've been going under the assumption we have that it's Rock, then Christy. If he wants to discuss it, we'll discuss it. Right now it's Rock, Christy.
THE COURT: Okay. And then --
MR. BOOKBINDER: Dr. Berck.

THE COURT: Dr. Berck. Okay. So you have a full day. There's no hole in the testimony; is that correct?

MR. CLUBOK: We sure hope not, Your Honor.

THE COURT: Well, according to Mr. Kline, there was some question as to whether there was a gap, but not -- not true.

MR. KLINE: I think it depends on the pace. That's all --

MR. BOOKBINDER: I can ask very slow questions, Your Honor.

MR. KLINE: No, no, no.

THE COURT: No, no, no. Okay. Do we have a calculation as to the time at this point?

COURTROOM DEPUTY: Plaintiffs at 33 hours and 45 minutes. Defendants at 33 hours and 40 minutes.

THE COURT: Well, you're both -- you're both right about exactly the same. You're both right around 33 hours and 40 minutes, which means technically you have six hours and 20 minutes, approximately, both sides. You're both at the same spot. So six hours and 20 minutes. My guess is that means that we will be ending -- if you use the last second, both of you, we'd be ending by the end of the morning on Tuesday; and if we go later in the next couple of days, we'll be --

MR. HEMLEY: This gap issue is a real issue,

because if the defendants can't build the day tomorrow -- and we understand the Court is going to be elsewhere on Wednesday of next week, then we have some -- we may have some requirements to stay late or start early or do something so that all that is remaining within our allotted time can be done because of the availability of witnesses.

THE COURT: You've got three expert witnesses for tomorrow. Isn't that plenty?

MR. CLUBOK: I would hope so. We'll work it out, Your Honor.

MR. BOOKBINDER: Your Honor, I can't imagine that we're going to be having any sort of gap. Maybe tomorrow for once we'll actually leave at 3 o'clock or 3:30. That's the worst-case scenario.

THE COURT: If you use up five hours tomorrow, then we're down to eight hours, only eight hours left.

MR. BOOKBINDER: And we can have a nice long day Monday.

MR. PAWA: If we have a gap, we'll call Mr. Hemley.

THE COURT: To talk on evidence.

MR. PAWA: Yeah.

THE COURT: All right. Thank you. So we'll see you tomorrow at 8:15.

(Court was in recess at 5:07 p.m.

C E R T I F I C A T I O N

I certify that the foregoing is a correct transcript from the record of proceedings in the above-entitled matter.

_____ _____

Date Johanna Masse, RMR, CRR