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UNITED STATES DISTRICT COURT

NORTHERN DISTRICT OF CALIFORNIA

BEFORE THE HONORABLE WILLIAM H. ALSUP, JUDGE

THE PEOPLE OF THE STATE OF CALIFORNIA, acting by and through Oakland City Attorney BARBARA J. PARKER,

Plaintiff and Real Party in Interest,

VS.

BP P.L.C., a public limited company of England and Wales, CHEVRON CORPORATION, a Delaware corporation, CONOCOPHILLIPS COMPANY, a Delaware corporation, EXXON MOBIL CORPORATION, a New Jersey corporation, ROYAL DUTCH SHELL PLC, a public limited company of England and Wales, and Does 1 through 10,

Defendants.

NO. C 17-6011 WHA

San Francisco, California

Wednesday
March 21, 2018
8:00 a.m.

Continued on next page.

Reported By: Katherine Wyatt, CSR 9866, RPR, RMR, THE PEOPLE OF THE STATE OF CALIFORNIA, acting by and through San Francisco City Attorney DENNIS HERRERA,

Plaintiff and Real Party in Interest,

VS.

BP P.L.C., a public limited company of England and Wales, CHEVRON CORPORATION, a Delaware corporation CONOCOPHILLIPS COMPANY, a Delaware corporation, EXXON MOBIL CORPORATION, a New Jersey corporation, ROYAL DUTCH SHELL PLC, a public limited company of England and Wales, and Does 1 through 10,

Defendants.

NO. C 17-6012 WHA

TRANSCRIPT OF PROCEEDINGS

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P R O C E E D I N G S

March 21, 2018 **8:00 A.M.**

THE COURT: Welcome everyone. Please be seated.

THE CLERK: Calling Civil Action 17-6011 and 17-6012, People of the State of California versus BP P.L.C., et al.

Counsel, please approach the podium, and state your appearances for the record.

MR. BERMAN: Good morning, Your Honor. Steve Berman on behalf of the People. And with me here today are City Attorney Barbara Parker, Erin Bernstein of the City Attorney's Office from Oakland.

Also with me from the City Attorney's Office of San Francisco is Robb Kapla, Matthew Goldberg and Ronald Flynn.

THE COURT: Great. Welcome to all of you.

And?

MR. BOUTROUS: Good morning, Your Honor. Theodore J. Boutrous, Junior. I'm here representing Chevron here today, and I'll be presenting the tutorial on behalf of Chevron.

Counsel for the other defendants have submitted a sheet of paper to speed things up with their appearances with the Court.

THE COURT: All right. Are all defendants present today?

MR. BOUTROUS: I believe so, Your Honor.

THE COURT: Including the ones who have objected to jurisdiction?

MR. BOUTROUS: I believe they are here and that their counsel made appearances.

THE COURT: Is that true? The other counsel?

UNKNOWN SPEAKER: Yes, Your Honor.

UNKNOWN SPEAKER: Yes, Your Honor, on behalf of Shell.

UNKNOWN SPEAKER: On behalf of Exxonmobil, Your Honor.

UNKNOWN SPEAKER: On behalf of BP, Your Honor.

THE COURT: Thank you. So just to be fair, all of you who have objected to jurisdiction and/or service of process, this will be deemed to be a special appearance. But I don't want you to hold back on the theory that if you say something you'll have waived your procedural argument.

So okay. Welcome to everyone, and thank you for coming. And I'm interested to see this turnout on such a wet, miserable day out there. We're going to have a tutorial on science in just a moment.

You all are ready to start?

MR. BERMAN: We are, Your Honor.

THE COURT: Okay. So let me just say to you two, as well as to the public, that I read in the paper a couple of weeks ago that this was going to be like the Scopes Monkey Trial. And I was -- I couldn't help but laugh. But this is not a trial.

I want everyone out there, the newspaper people, please don't call this a trial. This is not a trial.

In these technology cases, mainly the patent cases, but not just patent, we often have these tutorials so that the poor Judge can learn some science, and it helps to understand the science.

So you will find this probably boring. This will not be withering cross-examinations and so forth. It will be numbers and diagrams. And if you get bored you can just leave. Okay?

But I'm not promising fireworks or anything like that. This is a serious proposition to try to educate the Judge. So that's the purpose.

Now, we're going to proceed today in two chapters. Chapter one is the history of the development. There's a name for that that I've forgotten the history of the history. But, anyway, that's part one.

Then, part two will be the best available knowledge that we have today on the issue of carbon dioxide in the atmosphere and how that affects global temperature.

So are we ready to start?

MR. BOUTROUS: We're ready, Your Honor.

THE COURT: So what I want to do is on the first part give each side an hour.

Plaintiff, you can go first.

You can go second, Mr. Boutrous. And if you want to reserve any of your one hour, you can, but you don't have to. But don't ask for more time if you use up your one hour.

So you want to reserve anything or not?

MR. BERMAN: No reserve, Your Honor.

THE COURT: No reserve. All right.

MR. BERMAN: One housekeeping question?

THE COURT: Of course. Go ahead.

MR. BERMAN: And Mr. Boutrous was kind enough to accommodate this, if the Court would. I understand we're going to go one hour and one hour on history. We have a witness issue. And so if we could have just 20 minutes after the hour on part two, take them out of order a little bit.

THE COURT: What do you mean "a witness issue"?

MR. BERMAN: Well, he's got a conflict. He's got a conflict. He has to be somewhere else in the afternoon, and he's our --

THE COURT: Is this person going to be presenting?

MR. BERMAN: Yes.

THE COURT: Oh, so you want to do what?

MR. BERMAN: I want to have part of my part two right after part one.

THE COURT: And that's okay with you?

MR. BOUTROUS: That's okay with me, Your Honor.

THE COURT: Okay. That's fine.

MR. BERMAN: Thank you.

THE COURT: We might take a break in there somewhere, but I want to give you great flexibility. You can split this up any way you want. They are not going to be under oath. This is not cross-examination. That will all come later if we get that far.

So you can use an expert for part, all, anything you want to do. And the lawyers can do it. It's perfectly okay.

Okay. Ready?

MR. BOUTROUS: Yes. Thank you, Your Honor.

MR. BERMAN: Thank you, Your Honor. Again, Steve Berman.

THE COURT: The floor is yours, Mr. Berman.

MR. BERMAN: Thank you, Your Honor. I'm going to, first of all, hand out some handouts, if I may.

THE COURT: Sure.

MR. BERMAN: This is a notebook for you. I have one for your clerks.

THE COURT: Yes, please.

MR. BERMAN: Also, I have a timeline, historical timeline we'll hand up, as well, in horizontal format, as you requested.

THE COURT: Great.

MR. BERMAN: I'm going to call as our first speaker, Professor Myles Allen. Professor Allen is from Oxford. He's in the School of Geography and Environment, in the Department of Physics.

His resume is in the first tab in your notebook. He received the Appleton Award from the Institute of Physics for his contribution to the detection and attribution of human influence on climate change.

And before he comes up, I want to say one thing in response to Your Honor's comments. We view this, just so the audience understands and the Court understands where we're coming from, as science. This is not, as the papers called it from our perspective, our time to say when the defendants knew about climate change and what statements they made. We're just talking about the science of climate change today.

THE COURT: Well, I appreciate that. I hope we stick to that and keep politics and -- you know, I know that there are -- there's politics sometimes involved in this, but I -- let's stick to the science, if we can.

All right. So give me the name of that -- of your presenter. Professor?

MR. BERMAN: Myles Allen.

THE COURT: Myles A-L-L --

MR. BERMAN: Myles, M-Y-L-E-S, Robert Allen, A-L-L-E-N.

THE COURT: Okay.

MR. BERMAN: He's from Oxford. He talks a little funny, but I'm sure you'll be able to understand him.

THE COURT: Very good.

Now, are you Dr. Allen?

DR. ALLEN: I am, yes.

THE COURT: Okay. So what -- see that microphone there? Try to -- it's a good microphone, but it's got to be directed toward your voice so the public can hear.

DR. ALLEN: Thank you.

THE COURT: It's important that the public hear, too.

DR. ALLEN: Yes.

Thank you. Thank you, Your Honor. And we deeply appreciate the opportunity on behalf of the scientific community to present the history of the science of climate change, the evolution of our understanding of how carbon dioxide has affected global climates.

And the way I will -- it's difficult to explain the history without also explaining the science. So my presentation will combine the two, as will the others after the -- as will the later presentations, as well, and explain to you how our -- both what our current understanding is of the basic physics of how carbon dioxide affects global climates and how it's evolved over the past century.

And then, the following two experts will talk about the modern understanding of what is happening in the U.S. and California. The way I'm proposing to structure my talk is to talk about initially just the basic physics of how rising CO2 causes global warming. And, in particular, then I shall go on to looking at the -- looking at the understanding where carbon dioxide is coming from and going through the common cycle, and how that understanding has evolved over the centuries.

I'll talk about our bottom-up approaches to quantifying how much warming to expect as a result of a doubling of preindustrial carbon dioxide concentrations, for example. And then, top-down approaches to try to quantify the scale of human influence on global climate, recognizing also the role of natural influences in climate change.

There will be at that point a brief digression on ice ages. The Court specifically asked about our understanding of ice ages, so I will take you through that.

But we will then come back to our main line of evidence, which is our understanding what has been happening over the past century.

I will conclude with talking about how rising temperatures are affecting sea level and the permanent cumulative impact of carbon dioxide emissions from fossil fuels.

So we begin with the basic physics. And going back, we have to go back now to the early 19th century. Fourier and Tyndall understood the -- they knew about a mysterious, invisible form of energy, infrared radiation, which had been discussed and discovered only a few decades earlier. And Fourier, with a remarkable piece of intuition, recognized that the Earth had to get rid of the energy it received from the sun in this form.

And that he speculated that the atmosphere played a role in keeping the Earth warmer than it would otherwise be by interfering with this outgoing infrared radiation. But he didn't quantify this effect, specifically.

John Tyndall, an Irishman, then identified the specific greenhouse gases, carbon dioxide and methane, in particular, and characterized the way they interact with infrared radiation.

Now, among your questions you raised specifically this question of how it is that certain gases interact with radiation and others don't.

So that's illustrated in the next slide, which shows a carbon dioxide molecule. It's a molecule of a carbon. That black blob in the center is the atom of carbon, and two atoms of oxygen.

Normally, a carbon dioxide molecule is straight, but it can move in many ways because of its temperature. In particular, it can bend, vibrate up and down, and it can also -- and it can also vibrate from side to side, unlike an oxygen or nitrogen molecule, which consists of two identical atoms, and, therefore, has many fewer ways of moving.

And, importantly, two of these modes of motion of the carbon dioxide molecule, the bending mode, which I've highlighted at the top there, and this asymmetric stretch mode, these create an asymmetric dipole, meaning there's more charge on one side than the other.

And just like a little antenna, this can therefore interact with the electromagnetic field.

So we're talking about a mini antenna interacting with the electromagnetic field specifically in the wavelengths associated with the infrared.

The Court asked whether carbon dioxide is also responsibile for --

THE COURT: Well --

DR. ALLEN: And I should have said at the beginning I'm delighted for you to interrupt me and explain, if I need to explain.

THE COURT: So you have like this one on the bottom left, you've got red, black, red.

DR. ALLEN: Yes.

THE COURT: And that's lined up?

DR. ALLEN: Yes.

THE COURT: So does it matter in the atmosphere whether the red, black, red is facing the Earth broadside, or what if it was the other --

DR. ALLEN: No. No.

THE COURT: Wouldn't make any difference?

DR. ALLEN: It doesn't matter.

THE COURT: Okay.

DR. ALLEN: It doesn't matter. What matters, just like the radio --

THE COURT: But with the radio it does matter if the antenna is broadside to the signal or not.

DR. ALLEN: Your Honor's quite correct. Thank you for raising that. But in this case, because we have a mixture of molecules in the atmosphere, we see the combined effect of all of these orientations of molecules. And these interact with infrared radiation.

And, yes, Your Honor's quite correct. The orientation of the molecule would affect the polarity of the emitted photon or infrared radiation. But since this doesn't actually affect the amount of energy lost, we don't need to concern ourselves with this.

THE COURT: Well, this infrared is coming off the Earth. Right? And it gets somewhere into the atmosphere. And it passes by one of these CO2's.

DR. ALLEN: Yep.

THE COURT: Here's what I don't quite get. As it goes by, describe the step-by-step of how that energy gets absorbed into the molecule. And then, after that does it then get re-radiated again somewhere else?

DR. ALLEN: Yes.

THE COURT: It's unclear to me how that works. So please go ahead.

DR. ALLEN: So because the molecule -- the molecule in its ground state is sort of like this: Straight (indicating). Okay? And if a photon interacts, comes, as it were, close enough to it to interact with it, it sets it vibrating. Yeah? Like a chicken dance (indicating). Yeah?

Alternatively, sets it vibrating like an asymmetric stretch. I don't know what the name of that dance is. But, crucially, these are the modes of vibration that create an asymmetric dipole mode. This one doesn't do anything. Yeah? Because it doesn't make it -- so this mode of vibration --

THE COURT: What do you mean "It doesn't do anything"?

DR. ALLEN: Well, because it doesn't do anything to the dipole. If you measure, my head is the positive charge on top. My hands are the negatively charged oxygen. You can see that moving the oxygen in and out doesn't actually create a dipole. It doesn't -- it is still symmetric.

The average charge of the whole molecule is still zero in the center. Yes? Because I'm moving them. If I move these charges to and froe, I'm not moving the whole charge around.

Whereas, if I move them together, and then I've got the positive charge in the center, negative charges on either side.

THE COURT: There's some asymmetry.

DR. ALLEN: It is the asymmetry which is crucial. And the reason this is crucial is to now imagine I'm an oxygen molecule. So I just have the two hands up, the oxygen.

Now, there's no way that can vibrate to create an asymmetric charge, because the two halves of it are identical.

So that's why an oxygen molecule cannot interact with infrared radiation, but a carbon dioxide molecule can. And a water molecule --

THE COURT: So when it does absorb, the CO_2 does absorb, is it infrared or --

DR. ALLEN: It absorbs in the infrared.

THE COURT: Is that electromagnetic --

DR. ALLEN: Electromagnetic radiation.

THE COURT: -- that causes that movement that you described, the asymmetric movement?

DR. ALLEN: Yes. And then, it's left in this state (indicating).

THE COURT: Yes.

DR. ALLEN: And then, it releases that energy again, and it goes back to its original state. And it releases the energy in the same wavelength that it's absorbed it.

THE COURT: Now, right there. Okay. I've read some literature on this trying to get ready for today. Does the energy when it's released go into space or does it -- some go to space? Some go to the ground? Does it go in all directions or does it just get re-radiated back to the ground?

DR. ALLEN: It could go in any direction. And, crucially, the amount of energy that these molecules radiate is proportional to their temperature.

THE COURT: To what?

DR. ALLEN: And that brings us --

THE COURT: To what?

DR. ALLEN: The amount of energy these molecules radiate is proportional to their temperature.

And that brings us to the next crucial step in the argument.

THE COURT: Go ahead.

DR. ALLEN: Yes. Which was understood for the first time by a Swedish chemist, Svante Arrhenius. And he was the first one to quantitatively understand how rising concentrations of carbon dioxide affect -- could affect global temperatures or must affect global temperatures.

And I'm quoting here from his paper, which was published around the turn of the century, around the end of the 19th century. And this particular sentence is remarkably -- shows remarkable insight because he says:

"Any doubling of the percentage of carbon dioxide in the air would raise the temperature of the Earth by four degrees."

It's on the high side, but it's within the range of the uncertainty of the modern estimates.

But then, he goes on to say:

"If the carbon dioxide were increased by fourfold, the temperature would rise by eight degrees."

And it's interesting because, of course, the additional amount of carbon required to go from a twofold increase to a fourfold increase is twice as much as you need to go from a preindustrial to a twofold increase.

So what he's pointing out here is that every time you double you get the same amount of warming, which is not the most obvious. Sort of intuitively you might think that, you know, every ton of carbon put into the atmosphere has the same impact as the last.

And what's impressive here is therefore he's making a quantitative prediction, this sort of logarithmic relationship of carbon dioxide concentrations with temperature, which wasn't intuitively obvious.

And as a physicist we're always very impressed if someone has a theory that makes a prediction that is not completely obvious, which turns out to be true. And this prediction does, indeed, turn out to be true.

THE COURT: You said it was logarithmic. But if you double it, according to this quote, it goes up by four, and then --

DR. ALLEN: Four degrees.

THE COURT: Four degrees.

DR. ALLEN: If you increase it by fourfold, it goes up by eight degrees.

THE COURT: Right. So if you double it again it goes up by eight. So that seems -- that doesn't seem like logarithmic. That seems linear.

DR. ALLEN: So the doubling, it's two, four, eight, sixteen, by giving me each one the same amount of warming.

So if I was to plot carbon dioxide concentration in the horizontal and temperature in the vertical, you would see points going two, four, eight, sixteen.

THE COURT: All right. So if he had gone on to say eight, eightfold, then it would have been --

DR. ALLEN: Only 12 degrees.

THE COURT: -- twelve degrees.

DR. ALLEN: Exactly. Yes. You got it.

THE COURT: All right.

DR. ALLEN: So how did he come to this insight? Well, this shows essentially Arrhenius' reasoning. This is a view of carbon dioxide molecules in the atmosphere. And I've used color to denote their temperature. And you recall I stressed that the amount of infrared radiation emitted by these carbon dioxide molecules is related directly to their temperature. That was well-understood in the 19th century.

So colder is blue. So air gets colder with height. That's a well-known consequence of basic thermodynamics. And air also gets less dense with height, which is why the little carbon dioxide molecules are further apart as we go up through the atmosphere.

Now, if I try doubling the concentration of carbon dioxide in my model atmosphere, I want you to focus on the -- I would like the Court to focus on the lower right panel, which is the view of the atmosphere from above in the infrared.

So this would be analogous to thinking of the view of a house you might use with one of those cameras which one can take to see if you have got enough loft insulation. You know, they can do a color image of your house, and they show in bright red where energy is escaping from the house.

Now, if I double the amount of carbon dioxide in the atmosphere, it's like increasing the amount of loft insulation. And so we immediately see less energy escaping into space.

So that view from above now looks colder when viewed from space, because less energy is escaping as a result of the increase in carbon dioxide concentrations.

What's happened is that the additional carbon dioxide in the atmosphere is forcing the atmosphere to radiate heat from higher altitudes in order to escape into space. And because higher air is colder, it's radiating energy at a slower rate.

So if you reduce --

THE COURT: Say that last couple of sentences again.

DR. ALLEN: Yes.

THE COURT: I want to go back on your other -- okay. Say the last two sentences again.

DR. ALLEN: Sure. So because we've increased the total amount of carbon dioxide in the atmosphere -- and I should stress carbon dioxide is well-mixed through the atmosphere, so when the concentration increases, it increases everywhere -- photons, the little corpuscles of energy that are released by these carbon dioxide molecules, they can only escape to space from a higher altitude, because there's more carbon dioxide there getting in the way of photons escaping to space from further down.

And as a result, because higher air is colder, the amount of radiation escaping to space goes down. And, I mean, the diagram should make this reasonably intuitive. You can see as I -- sorry -- as I increase the amount of CO2 molecules, if I go back to the original, as I increase the amount of CO2 molecules, you can see there's been no change in temperature, if you look at the view from the side.

But looking down from above, we can't see as deep into the atmosphere because of all this extra carbon dioxide.

The atmosphere has become more opaque, so we're seeing higher air and less.

THE COURT: All right. I see your point there. But let me quiz you about that. You have started off with a large number of blue dots. Right? Looks to me like a large number of blue dots.

But the things that I've been reading say that the actual amount of carbon dioxide is trace elements. It's like 400 parts per million. But the way you've got it diagrammed there, it looks like 10,000 parts per million.

So is it -- would that make it -- in other words, if you started with just two dots there, and then you doubled it to four dots you would still see a lot of red.

DR. ALLEN: Your Honor is quite correct there. But, of course, even though it's only 300 parts per million, that's still an awful lot of molecules in a cubic meter of air, and crucially, a lot of molecules relative to the wavelength of infrared energy.

So infrared, infrared radiation has a wavelength much, much longer than the size of these molecules. And so the actual sort of -- the actual absolute number of molecules is not important. It's the opacity of the atmosphere in the infrared, which is entirely driven in this example by the amount of CO2 in it.

Because the oxygen and nitrogen molecules, as far as the infrared radiation is concerned, might as well not be there, because they can't interact with it.

THE COURT: What you're saying is even if there were just a small number of dots, as the infrared comes off the Earth the wavelength is long, so much longer than the molecule -- is that right, or something that --

DR. ALLEN: Yes.

THE COURT: -- that even though it doesn't hit it smack on, it just has to get close.

DR. ALLEN: Exactly.

THE COURT: Okay.

DR. ALLEN: So, in fact, it's the scale of the radiation that actually sets the chance of it hitting a molecule rather than the scale of the molecule itself. You know, the molecules are tiny. But the wavelengths we're talking about of infrared radiation are of the order of, you know, 10 microns or so. So that sounds like a small number. But compared to a molecule it's actually a huge number.

So that's why there's very little chance of a photon of infrared radiation emitted from the surface actually making it all the way through the atmosphere to space. It's around less than a sixth of a chance.

THE COURT: The point you made, the ones that are higher up are the ones that would emit radiation into space as opposed -- but wouldn't the ones that are further down, once they absorb, and then they re-radiate, wouldn't it progressively go up and still go out into space? Or is there some sort of diminishing returns problem?

DR. ALLEN: Oh, the atmosphere is being heated from below, for sure. But the crucial point which determines the net rate at which the planet as a whole can radiate energy to space is determined by the temperature of the molecules from which photons finally escape all the way out into space.

It's that sort of last emission that matters, because photons are bouncing around in the atmosphere all the time. But it's the ones that make it out into space that determine the rate of energy lost to space by the planet as a whole.

And so by adding more carbon dioxide in the atmosphere, we thicken this sort of foggy blanket of greenhouse gases around the planet. We force the planet to emit from a higher altitude, and, therefore, we reduce the rate at which the planet is shedding energy to space.

THE COURT: How would that affect what you showed me about what Tyndall said about what you said was the logarithmic relationship? How would it affect that?

DR. ALLEN: Let me show you what happens next. So we now have an imbalance. One of the crucial insights of Fourier and Tyndall was that carbon dioxide does not interact with solar radiation. In fact, the Court asked:

"Does carbon dioxide reflect solar radiation?"

The answer is: "It doesn't, and/or to a negligible degree." And, therefore, this increase in carbon dioxide has no impact on the amount of energy received from the sun. So no additional energy is reflected away because of the increase in carbon dioxide.

And, therefore, as a result, there's an imbalance now between the incoming energy from the sun and the outgoing energy to space, because the outgoing energy to space has been reduced as a result of the increase in carbon dioxide concentrations.

Because of that imbalance, the Earth has to warm up because it's accumulating energy at the surface and in the lower atmosphere.

And that's shown here by the warming, more red colors appearing. And it has to keep warming until the color in the lower left -- in the lower right is the same color as it was before, until it's releasing energy to space at the same rate that it was before.

Again, thinking back to the home insulation example, if you put more loft insulation -- if you put more insulation in your loft, then if you look at the house with the camera from outside it looks -- you see a bluer color because it's losing energy at a slower rate.

If you leave the heating on at the same rate, the house gets warmer, and the house will keep getting warmer until it's losing energy at the same rate. You might wind up uncomfortably hot.

So that's how the analogy -- it's not a bad one. It's not a great analogy, but it makes the point.

So this is why we get to this point about the logarithmic relationship. Suppose now after the warming I double carbon dioxide concentrations again. You'll notice that it has the same impact as the first doubling on the reduction in radiation into space.

Because of the way temperatures fall off with height and the density of carbon dioxide molecules falls off with height, every doubling of carbon dioxide has the same impact as the last on outgoing energy into space.

So that's, in essence --

THE COURT: Okay. Say that last sentence again. "Every" --

DR. ALLEN: Every doubling of carbon dioxide has roughly the same impact on the reduction of energy released to space as the last.

THE COURT: Well, give me a numerical example so that I can see that.

DR. ALLEN: So the first doubling might reduce outgoing radiation to space by 3.7 watts per square -- let's say 4 watts per square meter, for sake of the small number.

The second doubling, even though it requires twice as much additional carbon in the atmosphere to do it, would reduce outgoing radiation into space by an additional 4 watts per square meter.

And third doubling, which would require even more carbon, would also reduce radiation to space by 4 watts per square meter.

So the reduction in energy to space goes up four, eight, twelve, while the amount of carbon in the atmosphere goes up two, four, eight, sixteen.

THE COURT: Okay. I see what you're saying. I think I see what you're saying. All right.

DR. ALLEN: Crucially -- so this is the point here about if we compare that reduction with the impact of the first doubling, we see the same reduction in energy.

Crucially, you don't need to take my word for it. I do appreciate you're taking the time to understand this, this element of the basic physics. But we have seen this effect happening in observations made of the planet from space.

In a truly impressive sequence, series of observations, NASA flew an interferometer on the Nimbus 4 spacecraft in 1970. And a very similar instrument was flown by a Japanese satellite in 1997.

And by comparing these two spectra, by comparing the outgoing infrared radiation measured by these two satellites 27 years apart, John Harries, and his co-workers, in 2001 was able to identify the reduction in outgoing energy resulting from the increase in carbon dioxide and other greenhouse gases over the intervening 27 years.

So we've observed this effect that was predicted by Svante Arrhenius almost a hundred years earlier, we've observed it directly in satellite observations made of the planet as a whole.

THE COURT: Could you explain that graph?

DR. ALLEN: The graph at the bottom shows the spectrum of outgoing radiation. If you look very closely you can see there are two.

The difference between the two spectra's very small. This is a very fine and precise observation. It was only possible because of the extraordinary precision of those NASA engineers building that interferometer back in the late 1960's.

But we can actually see the reduction in outgoing energy to space, the change in the spectrum in outgoing energy to space that we would expect because of the increase in greenhouse gas concentrations.

THE COURT: I still don't get it. Is one of these -- is there a 1997 line?

DR. ALLEN: There's two lines there. One of the lines is 1970. The other line is 1997.

THE COURT: Are you sure? On mine it says "IMG" and "IRIS."

DR. ALLEN: Sorry. Yes. Yes. So the IRIS instrument was flown in 1970. The IMG instrument was flown in 1997. So they are 27 years apart.

THE COURT: But I don't see any -- they are so close together some people would say there's no difference. Where is the difference that you're pointing out?

DR. ALLEN: Well, the difference -- so I could -- I could give the Court a more detailed zoom-in on the figure from the Harries, et al paper. And I'd be happy to do so. I was just showing this spectrum as an illustration.

But there if you -- if you look carefully, as John Harries and co-workers did, at these two spectra, and also account for the various changes that have happened over the intervening 27 year periods, you can see directly the reduction in outgoing energy due to carbon dioxide and other greenhouse gases and in precisely the wavelengths you would expect to. You would expect to find that.

THE COURT: Which part of the wavelength is infrared?

DR. ALLEN: The infrared spectrum is -- this is -- by the way, this is the near infrared. This is only part of the infrared spectrum because it wasn't possible to measure the full infrared spectrum with the interferometers they were able to fly in 1970.

But it shows for the wavelengths that they could observe the reduction expected due to the increase in greenhouse gases.

So the crucial point here is that we don't just have a theory that rising CO2 opaques the outgoing spectrum of radiation, but we have direct observations from space of that theory.

THE COURT: I have to take your word for it because this diagram, to me it looks like it was very -- the only place I see a reduction is on 1300. It looks to me like there there is a reduction but --

DR. ALLEN: Okay. I would --

THE COURT: My eyesight gone bad or what?

DR. ALLEN: Okay. I would happily -- there is a -- I would happily furnish the breakdown which they give in their paper. I just put the spectrum in because --

THE COURT: You are the one that came up with the chart, and I just don't think your chart demonstrates what you're telling me. And I take your word for it that that's what they concluded. Okay. Good. I accept that point. But this chart doesn't convincingly show it.

DR. ALLEN: I'm sorry. I'm having to sort of take figures from scientific papers and sort of show illustrations of what we've done. And you are absolutely right. This doesn't, in itself, demonstrate the answer. And there are further diagrams in the paper which I could --

THE COURT: Forget the chart for a minute. When they did these satellite comparisons over the 27-year difference, what did they measure was the infrared reduction being emitted off the Earth in that twenty -- what was the reduction? Was it 10 percent, a hundred percent? What order of magnitude?

DR. ALLEN: In the wavelengths -- in the wavelengths that were being affected, I mean I'd have to get the numbers. But they were seeing over that period -- a useful way of thinking of it is in terms of the equivalent temperature of those molecules. That's a useful unit to use.

They were seeing a reduction of several degrees in the equivalent temperature of the molecules they were observing at those particular wavelengths.

So it was a substantial change relative to the sort of warming we talk about in terms of -- so they were seeing a substantial reduction in the wavelengths that are affected by these particular gases.

THE COURT: Okay.

DR. ALLEN: And, crucially, it was the reduction of the size and in the frequencies that we would have expected to see that reduction as a result of the increase in greenhouse gases. So we've observed this effect directly from space monitorings.

THE COURT: All right. So you jumped from Tyndall to the space satellite, but there must be something in-between. I'm interested in the history, too.

DR. ALLEN: Yes. I'm just coming back to the history.

So I was also going to stress that the models we use for weather forecasting incorporate this basic physics of how carbon dioxide and other constituents of the atmosphere interact with infrared radiation. And these are tested millions of times per day in performing the weather forecasts.

But to get back to the physics, Gilbert Plass, in 1955, during the sort of early part of the 20th century, he noted that there had been some criticism of this CO2 theory, because people had observed -- other scientists had observed that water vapor also absorbed strongly in the infrared wavelengths that were absorbed by carbon dioxide.

So in his paper in 1955, Gilbert Plass noted correctly that at the altitudes in the regions and also in the wavelengths that matter for carbon dioxide, the air was relatively dry because they were above the moist lower atmosphere, and therefore carbon dioxide was the dominant greenhouse gas.

So even though people had noticed the water vapor absorbed strongly at the surface, as those diagrams illustrating the outgoing radiation to space actually emanates from further up in the atmosphere above the moist lower troposphere above the moist region near the surface where water vapor is less important.

It's still an important greenhouse gas, but carbon dioxide plays a big role because the radiation is emerging from these dry regions of the atmosphere where water vapor doesn't get in the way.

THE COURT: So okay. I'll save my questions.

Go ahead.

DR. ALLEN: Near the surface -- I mean, near the surface, so in the conditions in this room the main absorber will be water vapor because, you know, the surface, you know, is warm. It can hold a lot of water.

And so because of the enormous amount of water vapor in the atmosphere, the actual amount of attenuation by CO_2 between one side of this room and the other would be less than the attenuation by water vapor.

However, Gilbert Plass' crucial insight was it doesn't matter what is happening in this room. What matters is what is happening at the emission level, at the level at which the planet is actually radiating energy to space.

And at those altitudes, because we're higher up in the atmosphere and the air is colder, it can now hold less water. The air is dryer and CO2 plays a dominant role.

THE COURT: Is CO2 lighter than oxygen and nitrogen, or does that even matter, the relative weights?

DR. ALLEN: A CO2 molecule is heavier than nitrogen and oxygen, but it is -- that doesn't affect the fact that it is well-mixed through the atmosphere. The individual molecular weights only matter when you get right up into the fringes of the --

THE COURT: So the concentrations 10 feet above the Earth are about the same as at 10 miles above the Earth?

DR. ALLEN: In CO2, yes. But in water vapor absolutely not.

THE COURT: Right. Okay.

DR. ALLEN: Because water vapor, as we know, as soon as the air cools, condenses and so on. So there's much less water vapor around as you go up through the atmosphere.

THE COURT: So Gilbert Plass, his point again was what?

DR. ALLEN: Oh, his point was he picked up Arrhenius' work. He noted that over the intervening decades Arrhenius' work had been criticized by people observing strong absorption by water vapor.

And he then made the point, yes, there is strong absorption by water vapor at the surface, but at the altitudes that matter for the planet's energy budget, CO2 is still the dominant greenhouse gas.

So he -- I mean, it's interesting. It's been very interesting for me as going back over these papers, one tends to find the papers which are right, because they survive.

And so it's only in the sort of asides in these papers that you learn about the papers that were wrong.

And so evidently there were a bunch of papers published in the 1930S's, or so, sort of poo-pooing the carbon dioxide theory, because there were a lot of them that were talking about water vapor.

And so Gilbert Plass was pointing out yes, that absorption happens at the surface, but it doesn't -- it's not happening at the rate to interfere with CO2 at the altitudes that matter for the energy lost to space.

THE COURT: Okay.

DR. ALLEN: So coming home from this, Plass also emphasized the need -- having sort of reidentifying carbon dioxide as a very important greenhouse gas.

I sense you checking the time, but don't worry. That was the longest component of my talk.

THE COURT: I'm absorbed by this, but I want you to know that I am going to keep a clock on both sides.

DR. ALLEN: I do appreciate the constraint, and I will do my best.

So -- and so but the next -- but the question was still open in the 1950's, up to the 1950's: How much fossil fuel emissions were likely to affect the global atmosphere?

One thing which people had noticed was that there was 40 times more carbon in the oceans than in our total fossil fuel reserves, even if you burnt the lot.

And so that might have made you think, well, you know, if we release all this carbon, it would just get diluted by the oceans, and it wouldn't really make very much difference in the long run.

Roger Revelle, in 1957, made the crucial observation that some simple high school chemistry, sort of buffer chemistry, limits the amount of carbon dioxide that the ocean can take up.

Carbon dioxide -- well, carbon exists in the ocean in three forms. If we -- if you'll bear with me and we ignore biology for the time being.

The three forms are dissolved carbon dioxide, the hydrogen carbonate ion, HCO3- and the carbonate ion.

THE COURT: Say the last one again?

DR. ALLEN: The hydrogen carbonate ion, HCO3-, single minus, and the carbonate ion, C032 ions.

Every molecule of carbon dioxide that dissolves into the ocean, requires the conversion of a carbonate ion to a hydrogen carbonate ion in order to preserve charge.

It's a simple -- the operation of a buffer, the kind of things that one uses at school to maintain a constant pH.

It's a good thing this is happening, because otherwise the oceans would have acidified much more than they have done as a result of the solution of carbon dioxide into the oceans.

But what it does mean is it's that store of carbonates in the oceans that actually determines the capacity of the oceans to take up CO2 from the atmosphere. And only 10 percent of the carbon in the oceans is in the form of carbonate.

So Revelle's insight was that actually the oceans were ten times smaller than you might think as a carbon pool. And that, therefore, we couldn't count on the oceans to simply dilute away all the carbon we have been releasing from fossil fuels.

THE COURT: Is it true that Revelle initially thought that the oceans would absorb all of the excess, and that he came to this buffer theory a little later around 1957?

DR. ALLEN: You may know more of the history of this than I do in that case. I'm aware, as I say -- I read the right papers. I read the final papers, so to speak. So this is the paper.

Actually, I suspect it probably was the case in the sense that he was thinking about the problem.

THE COURT: He was an oceanographer. Right?

DR. ALLEN: He was an oceanographer. He was thinking about the problem.

THE COURT: Scripps.

DR. ALLEN: Exactly. He was at Scripps. And in the process of thinking about the problem he came to this crucial insight. And it was a good insight at the time.

Up until that time, you know, the community, they weren't sure how long it would take for the carbon to be taken up by the oceans. But the community were just aware there was this vast carbon store in the oceans. And, therefore, there was some doubt in the community as to whether fossil fuel emissions would actually make any difference.

So having made this observation, Roger Revelle, he emphasized -- and I think he used the phrase:

"We're conducting geophysical experiments." And he emphasized the importance of measuring CO2 in the atmosphere to see if it was actually going up.

Which brings us to the next crucial step in our story.

Charles David Keeling, also at Scripps, measured -- started measuring carbon dioxide in the atmosphere, Mauna Loa in Hawaii, very precisely in the late 1950'S.

And he saw the famous Keeling Curve, this annual cycle of carbon dioxide resulting from the, in effect, the respiration of the northern hemisphere. And -- but on top of that, a steady increase which could you not account for by respiration.

The Court asked essentially about what happens to carbon dioxide breathed in by humans and, indeed, by animal life and so forth.

That does play a role in determining this annual cycle. So the annual cycle shows the sort of annual growth and the annual growth and decay of forests in the northern hemisphere taking up and releasing carbon. But it cannot account for the upward trend.

And, in fact, we're seeing carbon dioxide levels rising to levels that have not been seen for over 20 million years.

They are now past -- well past 400 parts per million, around 410 parts per million.

THE COURT: Keep that chart there.

DR. ALLEN: This --

THE COURT: Explain the ones you have on the screen, please.

DR. ALLEN: Yes. So this chart shows the combination of David Keeling's observations in blue on the right, and ice core measurements of carbon dioxide going back over much longer period, back to zero on the left.

So those two different time scales here, the left-hand panel has almost ten times longer time scale. And because, of course, we can measure carbon dioxide contained in bubbles in ice very precisely back over many thousands of years, and we see that carbon dioxide concentrations have been relatively constant throughout the Holocene period.

THE COURT: This is -- that's like a 2000 year?

DR. ALLEN: Two thousand year record. Almost no change. In fact, I could take that record a few thousand years beyond that, it would also be flat.

THE COURT: You said 20 million at the top, but it's really only 2000. Is that right or am I --

DR. ALLEN: Yes. I've got another figure addressing that in a minute.

THE COURT: But let's pause on this one.

Let's see. It starts down at 280. I can't read that.

DR. ALLEN: The preindustrial concentration's around 280 parts per million, and we are now at 400, 410.

THE COURT: All right. So that is -- that's not a doubling, but what is that?

DR. ALLEN: Well, we're about in the units we need to use, which are, of course, logarithmic, we are just over halfway to doubling.

THE COURT: Say that again about logarithmic?

DR. ALLEN: Sorry. But you remember our discussion earlier about the fact that --

THE COURT: I do, but --

DR. ALLEN: So because there's a curve -- in fact, there was a paper my colleague just pointed this out. We crossed the halfway mark to doubling last year.

THE COURT: But when Arrhenius said "doubling," he wasn't talking logarithmic, was he? Or is that something you've added to it?

DR. ALLEN: No, he was -- I mean, the point about the logarithmic relationship is the fact that every doubling --

THE COURT: Did he use the word "logarithmic"? No.

DR. ALLEN: Yes.

THE COURT: No.

DR. ALLEN: Logarithmic? Well, he was writing --

THE COURT: Did he use -- in his paper did he use the word "logarithmic"?

DR. ALLEN: I'm not sure. He was writing --

THE COURT: Arrhenius, I'm talking about.

DR. ALLEN: Yes. No. He talked about the logarithm of carbon dioxide. He talked about the fact that --

THE COURT: No. No. That doubling thing.

DR. ALLEN: Yes.

THE COURT: Did he say that would be a logarithmic function?

DR. ALLEN: Well, it is a logarithmic function. If we go back to that quote --

THE COURT: No. I'm asking: Did he say that?

DR. ALLEN: Whether he used the word "logarithmic" in his paper, I mean, I don't know.

THE COURT: Okay. Don't answer. It's okay. But I don't want you reading modern day politics into this. I'd just like to know did he say it was a logarithmic relationship?

DR. ALLEN: So whether said -- whether he used the word "logarithmic," mathematically, if he said something equivalent, mathematician wouldn't care what word he used.

THE COURT: Yes, but the two examples he gave are not necessarily -- it could also be linear.

DR. ALLEN: Yes.

THE COURT: The doubling and quadruple thing.

DR. ALLEN: Yes. Yes.

THE COURT: If you look at those, that part if it's both linear and logarithmic.

DR. ALLEN: If a double -- if a doubling has the same impact as the last doubling, then it's logarithmic. If a doubling -- if the second doubling has twice as much impact as the first doubling, then it's linear.

THE COURT: Okay.

I'm not sure I agree with that.

DR. ALLEN: Can I use the board?

THE COURT: Well, first go back to -- if we are going to argue about this, go back to the very first chart where you quoted him.

DR. ALLEN: Arrhenius.

THE COURT: I want to see the Arrhenius chart.

Here we go. Right there. So he says any -- so 2X equals 4C. Right?

DR. ALLEN: Yes.

THE COURT: And 4X equals 8C.

All right? So I readily agree that that would fit a logarithmic, but for just two data points which is all we got here. Doesn't it also fit a linear function?

DR. ALLEN: You also have the third data point, which is preindustrial equals 0C. So 1X equals 0C. So there are three data points, because if you have no increase in carbon dioxide, then you have no warming.

So that's why there are three points.

THE COURT: Wait. So you're saying 0X. All right. Let's say 0X would equal --

DR. ALLEN: 1X. 1X. 1X equals 0C, meaning same as preindustrial.

THE COURT: All right. So I have to think about whether or not that's right. But I'll that your word for it that that is a logarithmic.

Okay. All right. I'm using up your time with my dumb questions. Okay. Go ahead.

DR. ALLEN: Okay. So where do we go to. Keeling and what's happened to carbon dioxide. So confirmation that this carbon dioxide was being created by combustion and not, for example, just being released by the oceans because of the warming was provided by some observations by Ralph Keeling, also Scripps, Charles Keeling's son, who showed that oxygen concentration in the atmosphere was falling at the same rate that CO2 concentration was rising, because, of course, to create a molecule of CO2, you need a molecule of oxygen, if you are creating that CO2 by burning carbon.

So that confirmed that this increase in CO2 in the atmosphere was being -- was caused by burning something, if there was any remaining doubt about that question.

We could also see from the lower panel here the isotopic signature. That's the ratio of carbon 13. Carbon 13 means it's a form of carbon which has 13 nucleons rather than the normal 12.

That isotope of carbon was declining again at precisely the rate we would expect if this additional CO2 in the atmosphere was appearing there because of combustion.

THE COURT: I haven't -- explain this upward chart here that has the green line going --

DR. ALLEN: The green line going up is this CO2.

THE COURT: I got that. What is the blue line then?

DR. ALLEN: The blue line are observations of the concentration of oxygen in the atmosphere.

Now, oxygen is almost 29 percent of the atmosphere is oxygen. So there's a lot more oxygen around. But oxygen concentrations are falling ever so slightly because we're using up the oxygen to burn the carbon to make the CO2.

THE COURT: Okay.

DR. ALLEN: So in --

THE COURT: And where did that data come from?

DR. ALLEN: The oxygen data?

THE COURT: Yes. I was wondering about that very point. If the amount of oxygen -- I know it's many times greater, but I had wondered, well, is it actually falling off ever so slightly?

And one of the books I looked at said that they couldn't measure it. But you're telling me they have measured it.

DR. ALLEN: It's been measured. It's very delicate measurements, because obviously there's a lot of oxygen there, so it's actually quite hard to measure a very tiny percentage-wise reduction. But he did measure it and he saw this very clear reduction in the ozone.

THE COURT: Who measured that?

DR. ALLEN: Ralph Keeling, Charles Keeling's son, actually did the oxygen measurement. And that was done in the 1990's. So --

THE COURT: What was the -- did the parts per million of oxygen decline somehow correspond to the increase in CO_2?

DR. ALLEN: The reduction in oxygen was exactly the rate that was expected if all of the CO_2, all of the additional CO_2 in the atmosphere was appearing there because of combustion. So this --

THE COURT: I'd be very interested in reading that. Is that in a paper someplace?

DR. ALLEN: Absolutely.

THE COURT: Okay. Can you tell me --

DR. ALLEN: Yes, I can provide that to the Court.

THE COURT: All right. Thank you.

DR. ALLEN: So now we get to the breakdown of where this carbon dioxide is coming from. These are the key sources of emissions per year over the past century. And as you can see up until the middle of the century the beige band, which is the emissions from land use change actually were more than half the total that the contributions from fossil fuels, coal, oil and gas have taken off in the second half of the 20th century.

If we add up these emissions over time, so this is taking those -- this --

THE COURT: Wait. Wait. Wait. Keep that. That's a very interesting chart. Who is the -- who constructed that chart?

DR. ALLEN: This is data from the Global Carbon Project, led by Corinne Le Quere, at the University -- now at the University of East Anglia. And they compile information on both where carbon is coming from and where it's going to in the global carbon cycle.

THE COURT: Okay. So go back to the one you had up. Yes, that one. Just a minute. Let me -- "Land-use changes." Is that deforestation? What's included?

DR. ALLEN: Deforestation would be a big part of that. Also, conversion of land for agriculture. I mean, land-use changes is meant to be a value system. It's a formatted work.

And the key message of this is that land-use change emissions were really important up until mid-century. They have actually been declining in absolute terms since over the past few decades. And in relative to fossil fuels emissions, of course, they are now a relatively small fraction of the total.

THE COURT: And what's in the category of "Others"?

DR. ALLEN: That would be mostly cement manufacturing.

THE COURT: Gas is natural gas? Is that what that means?

DR. ALLEN: Yes, natural gas.

THE COURT: Hard to tell the difference between oil and the coal. I can't quite see it. Is there a difference? On my screen it's impossible to tell, but roughly present day what would be the difference.

DR. ALLEN: Present day emissions would be roughly -- of that lower band it would be roughly fifty/fifty oil, coal.

THE COURT: Okay.

DR. ALLEN: So if we go to -- so this shows exactly the same data, but just added up over time. So accumulating these emissions over time, and we can see from this that half of total emissions from fossil fuels into the atmosphere have occurred since 1980.

And we can also see the contribution from products sold by individual companies has also increased rapidly since the 1960's So it's possible to trace these emissions directly to products sold by individual companies.

Thanks to the work of the Global Carbon Project we understand where this carbon is going. About half of it is accumulating in the atmosphere. That's the pale blue band here (indicating). And other half is being taken up by the land and the oceans.

So the Court asked specifically about whether plants take up this additional carbon dioxide. And the answer is they do through something called a "CO2 fertilization effect." Plants grow faster in a higher CO2 world, and so they are taking up some of the excess carbon dioxide being put into the atmosphere.

Unfortunately, because of the warming that is going on, an even more important store of carbon on land, which is the carbon in soils, may actually start to release carbon because soil bacteria respire, and then release that carbon dioxide back into the atmosphere.

So the general consensus is that the ability of the land to take up excess carbon will weaken through the century, and it may even turn into a source.

Two: The crucial point here, and the main point of this is if you look at the thin, dotted line at the top here which is the total input from the sources, you can see that we can understand where that carbon has gone. So we know where the carbon is coming from, and we know where it's going. And about half of it is remaining in the atmosphere.

THE COURT: Wait. Let's try to digest this. "Atmosphere" I understand. "Ocean sink" I understand. What does "land sink" mean?

DR. ALLEN: That is the additional carbon which is being taken up by plants and soils in the land biosphere as a result of the plants growing faster, for example, due to the CO2 fertilization effect.

THE COURT: So let's say that we have the world pumping exhaust out of our collective tailpipes and the smokestacks and lots of CO2 that is definitely going into the atmosphere. So does this imply that some of that that goes into the atmosphere is then getting absorbed by plants for the green part, but it's from the atmosphere?

DR. ALLEN: So individual molecules are being cycled around all the time between these three different pools of carbon. What we're seeing here is the impact of the additional carbon dumped into the atmosphere on the carbon stored in both land and ocean. And you can see the more carbon is being stored on land than was before.

But, as I say, because of the impact of rising temperatures on soil bacteria, the concern is that the ability of the land to take up extra carbon may be becoming exhausted sooner, for example, than the ocean sink is likely to get exhausted.

I mentioned earlier Revelle's work showing that the ocean sink was smaller than expected. Well, we also have a land sink here, which is more complicated, involves more biology. But the result, there is evidence it's running out and its ability to take up half, to take up a quarter of the carbon we are putting into the atmosphere is running out.

THE COURT: In just a couple of sentences, what is that evidence that the land sink is running out of space?

DR. ALLEN: We know that as we warm soils, the bacteria in the soils -- there's more biomass in the world in the form of bacteria than just about anything else. So anything that changes the behavior of bacteria has a really big impact on global carbon cycle. And as we warm back the soil, bacteria respire faster, and then they convert carbon in the soil to CO2 just through respiration.

So that is a well-documented effect. But the magnitude of this effect is quite uncertain. So we don't know whether -- we know that it will reduce the effectiveness of the carbon sink.

We don't know whether it will be strong enough to turn it into a net source.

THE COURT: Okay.

DR. ALLEN: I now go to understanding the earlier, to understand the impact of increasing carbon dioxide concentrations on temperature. Just to come back to where -- you know, where we've got to, the increase in CO_2 and other forms of pollution in the atmosphere to date is a perturbation on the global energy budget of two-and-a-half watts per square meter. Two-and-a-half watts per square meter is the power consumption of a not very efficient cell phone.

So it doesn't sound like a very large amount of energy, but, of course, because the Earth surface area is so large it adds up to twelve-and-a-half million Terawatt hours per year, or 60 times global primary energy consumption.

So one of the questions the Court asked is: What happens to the energy that is actually generated by combustion of fossil fuels?

And the answer is: That energy, it might have a local impact in the vicinity of a power station or something. But globally, it's completely dwarfed by the impact of the emissions from those fossil fuels on the global climate through their interaction with infrared radiation.

THE COURT: Help me understand that part. So heat, the heat that is created by combustion, does that somehow -- I know your point about -- I understand you're making the point about the CO_2 is much more important to look at than the heat itself. But I do want to understand the heat part.

So we have heat -- technical name.

DR. ALLEN: Yep.

THE COURT: That is burning up and very hot, if you touch it. So that heat, does that at some point get converted to infrared energy?

DR. ALLEN: Yes.

THE COURT: Which then tries to get out in space?

DR. ALLEN: Yes. It becomes -- it warms the atmosphere. It eventually will be emitted in space as infrared energy.

THE COURT: How does it get converted? Does all heat -- does all just normal, thermal heat immediately start radiating infrared?

DR. ALLEN: Yep. Yep. It would potentially warm the air around it, for example, just directly warm the air. Or if it was water vapor being released from a cooling tower, then it would be released in the form of latent heat of water vapor in that steam. And then, that would condense. Many ways that that heat would escape into the atmosphere.

But its ultimate fate is same as all other heat, which is it radiates on in space as infrared radiation. But the crucial point here is that heat source is tiny compared to the impact of the emissions of CO2 on outgoing radiation through that impact on the greenhouse effect.

THE COURT: Is there any other planets in the solar system like Venus, maybe, that has an atmosphere that's more concentrated in CO_2?

DR. ALLEN: Venus absolutely has a lot of CO_2 in the atmosphere. And, in fact, one of the best tests of our understanding of the behavior of atmosphere is to look at other planets and understand. We use the same models that we use the model CO_2 on our planet. We use those models to model the behavior of other planets' atmosphere. And it's an excellent test of the physics which we incorporate into those models. And one --

THE COURT: What happens on Venus? How hot is it there?

DR. ALLEN: Well, the surface of Venus is extremely hot because it has what some call a sort of "super greenhouse effect."

The Venusian atmosphere is very different from the Earth. I'm also not a -- I mean, it has a very dense cloud cover, so the radiating temperature from Venus is determined by the temperature of very high clouds. Underneath the clouds, you have just like on Earth, you have this increase of energy with depth which just results from the fact that the atmosphere is getting more dense as it goes down.

And as a result, the surface of Venus is at many hundreds of degrees --

THE COURT: How about Mars? Doesn't it have CO_2?

DR. ALLEN: Mars has only a very thin atmosphere, and it doesn't have enough CO2. It doesn't have enough of an atmosphere to keep the surface warm, so Mars is relatively cold.

THE COURT: All right. So I'm using up -- your hour is up, but why don't you take five more minutes to wind up your first part of your presentation?

DR. ALLEN: Right. Okay. So there's sort of a natural break coming up pretty soon.

So we're in this situation. We've disturbed the global energy balance. And you can think of the global energy budget as like a bathtub. We've got an additional two-and-a-half watts per square meter going in because of this increase in greenhouse gas concentration. This is the situation I'm describing today.

We've got an additional 1.75, one-and-three-quarter watts per square meter going out because of the warming that's already happened. And there's a difference between those two numbers. So we have an additional three-quarters of a watt per square meter accumulating in the climate system.

THE COURT: The one where it says "1.75," does that mean it's going into space?

DR. ALLEN: It's going back out into space because the planet is already warmed as a result of past emissions.

And we can see this energy imbalance accumulating crucially in the world ocean. This is another very important milestone was that we were able to see the energy imbalance thanks to observations from Sydney Levitus.

And in 2000, he was able to show that the global oceans were warming again at the rate we would expect as a result of the energy imbalance due to the increase in greenhouse gas concentrations.

Which brings us to the way which we've framed our understanding of the climate system in terms of the global energy budget. And if I can have about -- as you say, I have about five more minutes --

THE COURT: Please go ahead.

DR. ALLEN: -- I can finish at a natural break. This is the way -- this is the only equation in my talk. It shows the situation now.

By the way, our understanding of the global energy budget was a lot of it down to the work of Stephen Schneider in the 1970's. Stephen Schneider, from Stanford. In fact, I'm sure if Stephen Schneider was alive today he would certainly be in this courtroom and probably giving this tutorial. So I'm doing my best.

We've already said the net energy imbalance due to external drivers about two-and-a-half watts per square meter.

We have the warming due to preindustrial of about 1 degree. And we also have this additional .75 degrees going into the oceans.

In equilibrium, we know what the forcing would be due to CO_2. That's 3.7 watts per square meter. And we know that the equilibrium warming, the thing which people have often been trying to work out, is what is the equilibrium warming due to doubling CO_2.

And the crucial part about this equation, this is an equation to represent the behavior of the climate system. But it contains two unknown quantities, these lambda and muse terms, which represent the additional radiation to space per degree of warming that results from the warming. And this is something which is -- which we can't derive. We can't observe it directly. It's not something we can observe. It's something we have to infer from other things.

And also an extra term, which is the additional energy released into space due to the fact that the system is now in disequilibrium.

And so we can work out the response to doubling CO_2 by putting all the mechanisms that we think affect these lambda and mu terms into a computer simulation. And this is the sort of bottom-up estimate of how we estimate the warming due to doubling CO_2 that is done with global climate models.

And the first of these modeling experiments were done by -- first of all, by Manabe and Wetherald in 1967, using a single-column model, which modeled the entire Earth as a spatial average. And then, later on in 1975, was using three-dimensional general circulation models.

It's important to stress these complex climate models get a lot of attention in the discussion of climate change, but they have appeared relatively late in my talk.

They weren't essential to our understanding of the impact of enhanced greenhouse warming.

Drawing all this together, drawing both our understanding of basic physics and understanding of the -- both understanding of the basic physics and the early simulations from global climate models, the 1979 National Academy of Sciences was able to draw the conclusions that they were expecting a warming of between one-and-a-half and four-and-a-half degrees for the equilibrium warming on doubling CO_2.

They also stressed -- and I suspect we can detect the hand of Carl Wunsch in these sentences -- that the oceans could delay the estimated warming for several decades. And, crucially, they made the statements:

"We may not be given a warming until the CO_2 loading is such that an appreciable climate change is inevitable."

So they not only identified the possibility of a serious warming, but they also recognized that it was going to be potentially awhile before we could see what was happening directly in the observations.

Reading these papers, it seems to me the situation in the late 1970's was somewhat analogous to a doctor who detects a virus count going up in a patient, but the patient has not yet developed a fever.

And the doctor might know that there's a one in three chance that the patient is resistant in which case the virus might continue up, but there would be no further symptoms. But there's a two in three chance that the patient could actually end up getting very sick. And so that's really the situation they were in.

They knew that if they waited until the patient developed a fever so that they knew whether or not it was a resistent patient or not, it would be too late to do anything about it. But they could see the virus is going up if you think of the virus as analogous to the CO2 molecules in the atmosphere.

So that seems to me to be a way of assessing their state of mind at the time.

And just to finish up, I want to sort of show you that it wasn't necessary for scientists in the late 19th century -- the late 1970's to detect the warming, in order for them to predict what was likely to happen next because of the fossil fuel emissions.

This is a figure from a paper by William Nordhaus, an economist from Yale. He was drawing from the climate science that was available at the time. And the dashed line on this figure shows his projection of the impact of rising CO2 on future temperature that results under a business-as-usual scenario of continued emissions.

And on the right here I'm showing you what has happened. And that's observed temperatures. I'm showing the pre-1977 observations in blue, red -- and the post-1977 observations in red.

And if I slide those over each other we realize that it was possible for scientists in the 1970's to make a remarkably accurate prediction of what has actually happened since 1980 to global temperatures.

And speaking as a climate scientist, I find it slightly sobering that such an accurate prediction was made when I was barely out of primary school. So --

THE COURT: Did he do this without the aid of computer models?

DR. ALLEN: He was using the results from the computer models that Syukuro Manabe and Richard Wetherald had run, but he was incorporating those results into a simple computer model of the climate system, and he was coupling that to make a computer model of the global economy, as well.

So this was the early efforts of the so-called "integrated assessment model exercise."

I think that's actually a good point to sort of illustrate to you the state of thinking at the end -- at the end of the 1970's.

The rest of my talk was about understanding how we detected human influence on the global climate over the more recent decades and the discussion of the role of natural and human influences.

THE COURT: Well, are you the witness who needs to go somewhere or is that somebody else?

MR. BERMAN: Somebody else.

THE COURT: Well, we're well past the one hour, so I think we have to move on.

And so, Dr. Allen, you are a genius. And thank you for helping me to understand this. I hope you stay with us for a while in case some other question comes up.

DR. ALLEN: I'm very happy to stay around. Thank you.

THE COURT: Thank you.

Let's see. Is it 20 minutes that you wanted? Tell me what your druthers are on time.

MR. BERMAN: We need 20 minutes.

THE COURT: Let's do the 20 minutes now, and then we'll take a break.

MR. BERMAN: Yes.

THE COURT: Can we do that?

MR. BOUTROUS: Yes, Your Honor. In part two of your topics you asked for a tutorial on the best science on CUIs and coastal flooding. So we're going to call Professor Gary Griggs to explain that topic to you.

THE COURT: Very good.

MR. BERMAN: Professor Griggs has a Ph.D. in oceanography. He's at the University of California at Santa Cruz. His resume is in your notebook. And also in your notebook, Your Honor, we did a Q and A of the questions you asked, the eight questions. There's a Q and A to those in your notebook.

THE COURT: Thank you.

All right. So you're Professor Griggs?

PROFESSOR GRIGGS: Correct, Your Honor.

THE COURT: From The Cruz.

PROFESSOR GRIGGS: The Cruz. I'm a banana slug.

THE COURT: The Cruz. That's where my daughter went, The Cruz. Okay. So please go right ahead.

PROFESSOR GRIGGS: Thank you for the opportunity to speak today. And I'm going to be talking primarily about sea level rise and how that relates to the climate change and also San Francisco Bay.

So the initial slide is just showing high tide today on the Embarcadero. Doesn't take physics or math to understand that.

This is just sea level for last 18,000 years. And sea level responds, very closely corresponds to climate change.

If we heat up the climate, heat up the Earth, ocean water expands and ice melts, which both raise sea level. And that's been happening -- we've had climate change happening ever since we've had an Earth and a Sun going back four-and-a-half billion years, plus or minus a few million. So as the --

THE COURT: What do you think caused the ice age?

PROFESSOR GRIGGS: We know the Milankovitch cycles, which you probably read about, where --

THE COURT: Yes, I did read about that.

PROFESSOR GRIGGS: Three orbital cycles with the Earth and the Sun. One of these is a wobble. It has a cycle of about 26,000 years. One is a tilt on the axis which gives us the seasons which has a cycle of about 42,000 years, and that tilt actually increases and decreases which takes us a little further away from the sun.

And then, the earth's orbit around the sun is an oval, or an ellipse rather than a circle. So that takes the Earth a little further away from the sun.

When you put all those three together, we start to see warmer and cooler periods that can begin to bring on an ice age. but there's also some feedbacks working. So, for example, as the Earth starts to heat up from those orbital cycles, the ocean gets warmer. It's releases carbon dioxide, which then adds to the warming.

We start to melt the Artic ice back. And instead of ice, which reflects sunlight, we have ocean left which absorbs heat. So that also adds to the heating effect. And permafrost starts to thaw and it gets warmer and more CO2 and methane are released.

So those we call "positive feedback loops." So those -- it's unclear if the Milankovitch cycles, those orbital cycles can completely bring on an ice age by themselves. But the timing fit's perfectly with those hundred thousand year, 42,000 year.

THE COURT: Does the oval elliptical -- I think you called it "elliptical orbit" -- does that change or around the sun or is that fixed, but the other two wobble?

PROFESSOR GRIGGS: So all three are changing on those cycles so that oval that takes us a little further away, and then comes back again, has a cycle of about a hundred thousand years until it returns to where it was before.

That wobble, roughly 26,000 years till it's back where it was. So each of those takes us a little further from the sun and brings us a little closer over time to bring on glacial and interglacial --

THE COURT: One last question on this. If the northern hemisphere and the north pole gets frozen over, does that then mean that the southern is exposed more to the sun and is tropical? What is the answer there?

PROFESSOR GRIGGS: Certainly during -- I mean, we're in northern hemisphere winter now. So this is the sun. The axis rotation, it's tilted, so we're further away and the southern hemisphere is having their summer.

When we get on the opposite side, we're now facing the sun.

THE COURT: Right.

PROFESSOR GRIGGS: If we go back in geologic time, we have had extremes. Again, before there were humans on the planet, we've had a period we call "hot house Earth" when all the ice melted. We had fossils of palm trees and alligators in the Artic.

And we've had a period called "snow ballers" when we think the entire Earth was frozen due to changes in things like methane released from the ocean. Some other things we're still starting to understand. So it may not be tropical in the South Pole, but it would be different temperature depending on whether --

THE COURT: It would not be frozen over like the north -- in other words, if the North Pole was completely Artic and frozen, then the South Pole would be warmer than normal; is that right?

PROFESSOR GRIGGS: Depending on where we are in our climate cycle.

The other difference is the South Pole Antarctica is a continent with ice on it, which we'll talk about in a second, whereas the North Pole is a sea covered with floating ice.

So the point here is at the end of the last ice age, about 18,000 years ago, things started to warm up quickly, and sea level rose quite rapidly, maybe a half an inch a year until about 8,000 years ago.

Again, this is in the absence of any real human activity on the Earth that was affecting that. Within that, however, within that rise there was some periods when sea level rose maybe an inch a year, which we can almost stand out there and watch. We think now those were due to ice sheet collapse in Antarctica, which is a concern.

About 8,000 years ago, sea level leveled off, and for the next 8,000 years, which corresponds to essentially the entire period of human civilization, sea level was constant.

So civilization has never before had to deal with a rapid change in sea level. Very slow rise over that period. That red dashed line is the present average rate of sea level rise from satellite measurements, a little over a foot per hundred years.

And in all likelihood, with the increasing greenhouse gas emissions and increased warming that rate is going to increase, and that's the thing that many of us are concerned about.

THE COURT: Can I ask a question? Way back there where the big arrow is, does that mean that the -- what would be the difference in height change? I'm not following that very well.

PROFESSOR GRIGGS: So on the right side is an elevation difference. At the end of the last ice age about 20,000 years ago, sea level was about 400 feet lower.

THE COURT: I got it.

PROFESSOR GRIGGS: So you could have walked out to the Farallons for lunch if you walked really fast.

THE COURT: Really? How about would the Bering Straits have been --

PROFESSOR GRIGGS: Yes.

THE COURT: You can walk across there?

PROFESSOR GRIGGS: And early humans did. We're quite certain of that.

THE COURT: So maybe in that period when it was low tide, so to speak, that's when they came across?

PROFESSOR GRIGGS: It didn't have to be low tide. The whole Bering Strait was exposed. And we've got lots of archeological evidence now of early humans making it into North America probably 25,000 years ago.

But the main point of that white arrow is that that rate of increase was very steep there, perhaps an inch a year, which looks like something happened fairly quickly, which we think was probably ice.

THE COURT: What do you think did happen that caused that ice age to melt away.

PROFESSOR GRIGGS: At that point we think a collapse of one of these big ice shelves, in other words, one of these glaciers moving rapidly into the ocean. And that's what I'm going to talk about in just a second.

THE COURT: Sure. Go ahead.

PROFESSOR GRIGGS: So this is -- I'm trying to think which one we're on. Yes, this is just a quick animation of sea level rising corresponding to that 20,000 year period. So this is the San Francisco Bay Area. And you can see, if this runs. Sometimes this works.

Let's see here.

THE COURT: This is going to be an animation that shows the coastline shrinking. Is that it?

PROFESSOR GRIGGS: Yes. Okay. We'll do it another way here. Is this up on the screen?

THE COURT: What I see is it's not that map anymore. It's a pretty picture of a sunset.

PROFESSOR GRIGGS: It's showing up on my screen.

THE COURT: Here comings a helper.

If it would help, we can take a break and let you fix it during the break.

PROFESSOR GRIGGS: Can you see that on the screen?

THE COURT: I can now. Okay. There. It worked. It worked. All right. Please go ahead.

PROFESSOR GRIGGS: We got to go back and do it again. So this is 18,000 years ago in --

THE COURT: Okay.

PROFESSOR GRIGGS: This is about the most embarrassing thing.

THE COURT: I think about 30 seconds you'll get it. Try that little YouTube thing that you had out there and click on that.

PROFESSOR GRIGGS: Well, the years are going by, but the water isn't moving. But it's moving on my screen here. What's wrong?

THE COURT: Okay. Here's what we'll do. You take a few minutes. We're going to take a break. It's time for a break, anyway.

PROFESSOR GRIGGS: Okay.

THE COURT: And when we come back maybe you'll have it fixed and ready to go.

PROFESSOR GRIGGS: Well fix it.

THE COURT: All right. Thank you.

PROFESSOR GRIGGS: Thanks.

(Thereupon, a recess was taken.)

THE COURT: Okay. Welcome back. Let's go back to work.

PROFESSOR GRIGGS: Okay. All right.

You're just going to have to take my word that the sea level rose from the Farallons, up to the Golden Gate, into the Golden Gate, up to Sacramento and back out again.

THE COURT: I'll take your word for it.

PROFESSOR GRIGGS: Okay. So this is just looking at sea level rise past, present and future back from the 1800's to the early 19 -- or the late 1800's we're using geological evidence.

Beginning in the late 1800's to the present we used tide gauges to measure sea level. And that black line shows the global average of about five-and-a-half inches per --

THE COURT: Wait. I made a mistake. I left my watch somewhere.

PROFESSOR GRIGGS: That's okay.

THE COURT: Wait. Let me see it. I found it. It's in my pocket.

Okay. Go ahead. You got some free time here.

PROFESSOR GRIGGS: So up until 1993 we used tide gauges, which was just water level recorders. We have one up at Golden Gate.

Tide gauges actually give you a local measurement. So it shows what the ocean is doing, it's rising. But if the land is rising or the land sinking, tide gauges will show you something different around the world. In Venice, it's sinking and in Alaska the land is rising.

In 1993, we lost a couple of satellites that measure global sea level from space. And those numbers are around 13 inches per hundred years on average. So maybe two-and-a-half times faster than those tide gauges.

And in this report, which I was involved with for the National Academy of Science and National Research Council, we were asked to project into the future. 2030, 2050, 2100.

So those are some of the ranges we got -- I won't go into detail -- based on different greenhouse gas emissions, and I'll come back to that in a second.

So if we look at cities around the world today, most of the; world's big cities are on the coastlines, because a lot of reasons. That was a good place to build. There's now Oakland and San Francisco here (indicating).

But maybe 200 million people around the world living within 3 feet of high tide. So sea level is an issue for a lot of places.

This is the tide gauge for San Francisco, which is out at the Golden Gate, the oldest in the country. And it averages about 7.7 inches per century. They weren't put in to measure sea level rise. They were put in to measure water depth so ships could come in and out without grounding on the bottom.

But what it's shown over time is the sea level is rising there.

This is now the satellite record since 1993. And the average rate, which I mentioned earlier, is about 13 inches per century. But if you look at the first several years, it's rising at maybe one-and-a-half millimeters per year, or six inches per hundred years.

The middle stretch from, say, 1997 up to 2009, or so, is equivalent to the long-term average of a little over 12 inches per hundred years. But if you look at the most recent it's at an even faster rate.

So it looks like from satellite measurements sea level rises are accelerating or increasing. The thing that concerns us is the ice on the planet. And there's three big chunks of ice. One are the mountain glaciers. Actually, not all that much ice. If we melt it all maybe we would raise sea level a foot and a half.

It's okay unless you live a foot and a half within sea level.

Greenland, if we melted it all would be about 24 feet. And Antarctica contains about 190 feet of sea level rise equivalent. So 216 feet total if we melt all that ice. No scientist thinks that's going to happen this year or next or this century or next century. But we don't need to melt all of it to create problems for coastal cities around the world or San Francisco Bay.

Just two years ago a couple of scientists, DeConto and Pollard, tried to figure out what was really happening in Antarctica. And they realized that there are times in the recent past, one about 130 million years ago, one about 3 million years ago, where sea level was 20 to 30 feet higher than today, but the temperatures were only slightly warmer.

And they feel the Antarctica ice sheet breakdown collapse was the reason for that. So what they did was put together the physics to try to understand what is happening and what could happen next.

State of California --

THE COURT: One more time. 130 million years ago what?

PROFESSOR GRIGGS: I'm sorry. 130,000 (sic) years ago and 3 million years ago were both warm periods when we know sea level was 20 to 30 feet higher than today, but the temperatures were only slightly warmer, which suggested something could happen fairly quickly and get us to those levels. And they wanted to understand what it would take for that to happen. Is that something that could happen, you know.

THE COURT: I thought you meant -- but did that mean Antarctica was underwater? I just didn't understand. I thought you said something about Antarctica in that.

PROFESSOR GRIGGS: Antarctica is where the biggest amount of ice is that looks like there's the greatest potential for --

THE COURT: Was it always ice? Was there ever a period it wasn't ice?

PROFESSOR GRIGGS: There's a period where Antarctica wasn't where it is today. It was further away in warmer climates, about 30 million years ago.

THE COURT: Since it got to the pole it's been covered with ice; is that it?

PROFESSOR GRIGGS: Right. Roughly the last 30 million years or so. I realize those are really big numbers and it's sort of like way back there, but it's been there for awhile.

So the State of California asked the Ocean Protection Council Science Advisory Team to look at the present status. I was asked to chair that committee. We finished that April last year.

And what comes out of that was first Antarctica holds about 61 percent of the earth's fresh water, about 190 feet of potential sea level rise. And the understanding that DeConto and Pollard came up with is this image that these huge ice sheets are being held in by these floating ice shelves.

And two things they began to understand are happening, and I kind of liken it to taking the cork out of a champagne bottle, if these ice shelves start to break up and move out, then these glaciers can advance. And they are now melting at the surface as the air gets warmer, and they are melting from underneath as the water gets warmer.

THE COURT: They are melting, are they the ones on land or sea?

PROFESSOR GRIGGS: The ones on the sea, these corks.

So they understood that you can't keep that thing melting and still keep it in place. And that these ice cliffs when it breaks off can only get so high. So when that happens those glaciers can advance more rapidly. And we do see ice shelves breaking off now, one in north part of Antarctica that is equivalent to the size of Delaware, which is fairly sizable.

So that the process is being witnessed and these are the findings from that report that we did just a year a little over a year ago. We know the direction of sea level rise. We see the rate of loss from Greenland and Antarctica are increasing.

This work highlights the potential for an extreme sea level rise. And we worked out probabilities. And those should begin to shape our decisions on how we begin to deal with coastal infrastructure, coastal facilities, coastal instruction.

And waiting for absolute scientific uncertainty is not a prudent option because of what is at stake.

This was a projection of what we saw potentially happening in the future. And on the left side, so there's today. The left side are the tide gauge and the satellite records. And then, we were tasked with looking out again to 2050, 2100.

And, basically, we used two of these RCP scenarios, which are these representative concentration pathways for greenhouse gases. A low one, 2.6, which is in the blue. And that's meaning that scenario means we get control of greenhouse gases very quickly. Huge reduction in carbon emissions. Do everything we can to stop that, those emissions.

The red is RCP 8.5, which means we just keep going as we are. Our use of fossil fuels continues. So you can start to see after 2050, after that second dashed line, those projections begin to diverge.

And we show both a midpoint, which is the solid line. And then those dashed lines, we are looking out at the ends of the distribution, the 5th and the 95th percentiles.

So by 2100, we could be 2 feet, 3 feet, 4 feet, over 4 feet. But then, there's also the potential like we saw on those earlier slides of a major collapse.

In the work that's been done in these models with greenhouse gas show it could be 8 feet or 10 feet. We don't know what the probability is, but we can't discount that.

So just to give you a little sense, this is the Oakland International Airport, which is all built on fill. And this is from a site that we can actually project future sea level at the Oakland Airport in Oakland, as a whole.

So this is today's high tide. This is if we add 1 foot of sea level rise. So the blue is now going to be wet. We can add 3 feet, and you can look around and see more of the airport in some areas of Oakland.

And I'm just going to use these, for example. We could add five feet and we could see a lot more of Oakland. The area around the Bay Bridge goes underwater. I didn't go to 10 feet, but 8 feet gets pretty grim. So we can look out in the future and see what those elevations mean for coastal areas and Oakland and San Francisco.

In addition to the sea level rise, which is this gradual sort of incline that's looking like it's going to get steeper, we also have these short-term events which become more important.

And El Niños are one of those short-term events. And those red arrows point to the major El Niños in 1941, 1983, 1997-'98.

So the tide gauge in San Francisco shows water level was a foot higher for several months.

This is just showing that event, and San Francisco, in particular, where the highest recorded level was 1.77 feet above what the tide table would have predicted -- projected from that El Niño, which is this warm bulge of water that moves up from the equator along the coast of western North America every 3, 4, 5 years.

So these short-term events are going to be problematic in the short-term, but as sea level continues to rise they are going to be on top of that.

THE COURT: In brief, why is it that an El Niño would have that surge effect?

PROFESSOR GRIGGS: So an El Niño occurs when the circulation of the equatorial Pacific reverses. Normally, the water moves from -- I'll do it facing you -- from the Trade Winds blow the water from the South America side over to the Western Pacific off the Philippines and Japan. Every three or four, five years, that system breaks down, the Trade Wind breaks down, and the water, this warm bulge of water in the Western Pacific flows back across to Ecuador and Peru. It shuts down upwelling the fisheries, and then moves north and south.

Brings a lot of warm water organisms, fish and so forth. So that bulge actually moves up the coast: California, Oregon, Washington, and moves down the coast of South America.

We still don't know exactly what drives an El Niño, but we've seen them happening and seen them in the geologic records for hundreds of years.

THE COURT: It's just the force of all that massive water that causes -- forces itself on the way to the land up by 1.77 feet?

PROFESSOR GRIGGS: Right.

THE COURT: Okay.

PROFESSOR GRIGGS: It's been called a "Kelvin wave," so it's like a wave of water sort of slowly moving up the coast over weeks or months. But it stays for a couple of months. So, again, that's on top of sea level.

The next several slides are the other short-term event, which we've now called a King Tide. So the tide is driven by attraction of the moon on the earth's water, and also the Sun, and those two working together.

Couple of times a year the moon is a little closer to the Earth, and the Earth-Moon system is a little closer to the Sun, so the gravitational pull is greater, and we get these extreme tides. So this is the Embarcadero at an extreme tide with today's high tide. I mean, today's sea level. And I just through a couple other ones in here. This has become sort of ground zero for King Tides.

So these are now coming on top of any slowly rising sea level around the Bay margin. Just recently another study came out that's looking at changing flood frequencies. And this is not river flood, but a coastal flood. So when high tides and storm waves wash water up into the public streets or the coastal area --

(Thereupon, an alarm sounded.)

THE COURT: Coastal flood alert.

PROFESSOR GRIGGS: From the 19th floor.

THE COURT: Once a month at 10:00 o'clock this thing goes off. And sometimes there's an announcement. Usually not. But about one out of three times they come on and tell us not to worry.

I suggest you go ahead, but they may interrupt.

PROFESSOR GRIGGS: I just got two more slides.

THE COURT: Go ahead.

PROFESSOR GRIGGS: So basically what this is showing, the bottom two panels, are the top is under intermediate emissions scenario, RCP 4.5. This is telling us -- and I'll pick San Francisco because we're here -- that the 10-year flood, which means it would have happened on average about every 10 years, will now happen 6.8 times a year by 2050.

By 2100, the 10-year flood in San Francisco will occur every third day because the water's now higher than it was before. So these extreme events are going to push the water even higher.

If we go to the bottom panel -- and I'm not going to go over to the 500-year flood. That's way beyond our lifetime.

The bottom is RCP 8.5, which is really our today. That's the direction we're heading. And what that shows by --

THE COURT: "RCP" means what?

PROFESSOR GRIGGS: Representative concentration pathways. And that's how many watts per square meter the Earth is sort of gaining heat. It's just a measurement that has been used to talk about how much more warming.

So if you look at 8.5, you know, we can look at 2050 again in San Francisco, the 10-year flood, which would have occurred once every ten years is now coming 10 times a year, because the water level's higher, and these other -- these King tides, these El Niños, these storms events are going to simply be further inland and higher in elevation.

So based on all the work we did on the rising seas report the state put together a sea level rise guidance for all the state agencies.

This was just accepted by the Ocean Protection Council last week. And, essentially, it's giving direction as the sea level continues to rise, how each individual facility or future construction needs to take into account the future projections based on the tolerance that that particular facility can manage.

Is it an airport? Is it a bike path? Is it a walkway? And so the state is now invested in these, and we're looking to how we're planning for the future.

Thank you very much.

THE COURT: Thank you. All right. So just to -- it's your turn, Mr. Butrous. And here's what I suggest we do. The Plaintiffs' side has about 30 minutes left total, because of your -- that took actually more than 30 minutes but -- and so I think we ought to do the defendants' side on both presentations, and then the Plaintiffs' side will have 30 minutes at the end.

All right? Your turn.

MR. BOUTROUS: Thank you very much, Your Honor. Really appreciate the opportunity to be here to address the questions and issues the Court identified in its request for tutorial regarding climate science.

I'm here today representing Chevron Corporation. Chevron does not do original climate science research. Chevron accepts the consensus of the scientific community on climate change.

That scientific consensus is embodied in the results of the Intergovernmental Panel on Climate Change, the IPCC. And that has been Chevron's position for over a decade.

And before we leave today we're going to leave behind a couple of pieces of the lengthy reports from the IPCC and also give you guidance on easy ways to get to those reports and also provide our timeline. And we also have a hyperlinked timeline for the Court. We'll figure out the best way to transmit it so the Court can use that.

The IPCC's latest report issued in 2013 is known as the Fifth Assessment Report, or AR5. And you are going to here quite a bit from me about that because it's an amazing resource, Your Honor, in terms of collecting and assessing the work of scientists and work that goes back to 1988.

And that report is literally the collective work of thousands of scientists and experts, including, I believe, Dr. Allen, who started off today. And it was very interesting listening to Dr. Allen. He's one of the thousands of scientists who participate and have participated in this IPCC process to reach a global scientific consensus.

And as I mentioned, the most recent IPCC report, was issued in 2013, is called "AR5." And it concluded -- and I'll just read it, and quote it.

Quote:

"It is extremely likely that human influence has been the dominant cause of the observed warming since the mid-20th century," close quote.

And I'm glad the Court mentioned the Scopes Trial talk out there because from Chevron's perspective there's no debate about climate science. First, because Chevron accepts what this scientific body and includes scientists and others, but what the IPCC has reached consensus on in terms of science on climate change.

But also because it won't surprise the Court we believe the resolution of climate science issues aren't going to be determinative here for all the reasons in our motion to dismiss.

That's for another day.

From Chevron's perspective there's also no debate about another of the IPCC's conclusions. And that's climate change is a global issue that requires global engagement and global action.

And that global action requires a balancing of these environmental issues, the climate issues with issues of energy security and socioeconomic issues.

In other words, global warming presents complex international policy issues based on this scientific consensus that has been reached up till the 2013 report. And it's continuing to evolve.

The AR6 is coming out in 2021. So scientists are, you know, looking forward to that 2021, there's going to be a new IPCC report then with new conclusions and evolving science.

Chevron does not agree with all the policy proposals analyzed by the IPCC. It includes not just the science in Working Group 1. And I'm going to come back to this. But it also includes sections that have -- they don't recommend certain policies, but it's meant to give policymakers a predicate for debating and making these decisions.

AR5 itself notes these are complicated policy issues about the future currently being debated by individuals, communities, countries, NGOs, international organizations.

So as a preclude to launching into my detailed discussion, I want to make clear that this is not a case about a dispute concerning the consensus of climate scientists.

It is about the policy choices that have been made, including by Oakland and San Francisco, and the policy choices to be made in the future. And it's about whether a tort suit like this one is the right way to debate and decide those policy choices.

Here's my plan, and for part one of the tutorial, Your Honor. First, I will explain how climate science developed. I think Dr. Allen covered much of the areas. But there are a couple of areas I'm going to try to fill in a few blanks here. And I think the Court was asking some questions that got to that.

Then, I'll describe the evolution of the science on greenhouse gases and the growth of scientists' understanding of their impact on climate change.

And throughout the day I'm going to be referring to most often AR5, the IPCC report. There's also a synthesis report, which includes the summary for policymakers. And then, it really captures this thousand-plus page report. And we'll leave a copy with the Court of that, as well.

Before I jump into the history, I want to talk a little bit more about the IPCC, because I really did appreciate the Court's tutorial saying:

"Let's take a look at what's out there in terms of science. What's the history?"

And as I said, the IPCC materials are really an extraordinary body of literature. IPCC was formed in 1988. It's an international body established by the World Meteorological Organization, WMO, and the United Nations Environmental Program. And I think 195 countries participate.

And as I suggested, the purpose is to assess the scientific, technical and socioeconomic information necessary to understand climate change and assist policymakers in addressing it.

The IPCC also evaluates potential impacts from climate change as well as adaptation and mitigation issues and measures.

The IPCC is divided into three working groups. And I've just displayed a chart from the IPCC itself that explains what they are.

The first working group is the one I'll be really focusing principally on today. It's the group that addresses the science of climate change, the physical science bases.

Working Group II is the group that addresses socioeconomic impacts and policy options for adapting to climate change.

And then, Working Group III is the group that addresses options for mitigating for climate change. Seeing if we can restrain it, if we can stop it or slow it from occurring.

And the Working Group III discusses policy options for limiting greenhouse gases and enhancing activities that remove them from the atmosphere, as well as the costs and benefits of different approaches to mitigation.

So that structure really reflects the over-arcing purpose of the IPCC.

Now, I mentioned the assessment reports. And I think it's -- they are very illuminating. The first one was in 1990 and most recent one was published in 2013.

To give you an idea of the work that goes into these reports for AR5 alone, there were more than 830 authors and review editors from more than 80 countries.

They drew on the work of over a thousand contributing authors and about 2000 expert reviewers who provided over 140,000 review comments.

When I saw that I thought of the person who had to incorporate all the comments into the final draft. Quite the task.

But the reports describe the current understanding of climate science at the time they were issued, including areas of uncertainty and areas where additional research was needed.

And, in fact, the reports talk about the uncertainty and probabilities and likelihoods in very specific ways, so some of the quotes that I'll direct the Court to include "very likely, likely." The one I showed "extremely likely."

Here's the chart from AR5 that -- we're going to leave behind our slides, as well, for the Court. But this, the chart expresses how likely something is. And so the top chart measures confidence in terms of how much agreement there is among scientists and the quality of evidence supporting the finding.

The IPCC also has terms to express the probability of a specific outcome, ranking from "exceptionally unlikely" to the "virtually certain."

And that's at the bottom of the screen.

"Extremely likely" is not on this chart, but the IPCC notes in its report that they view that as a 95-100 percent likelihood. So we've got a note on that there.

The IPCC report, it addresses key uncertainties in its own words.

So if we look at AR5 Technical Summary, the IPCC summarizes the key uncertainties that still exist in climate science.

And I'll just read the first sentence there:

"This final section of the Technical Summary provides readers with a short overview of key uncertainties in the understanding of the climate system and the ability to project changes in response to anthropogenic influences," close quote.

And the IPCC alternately refers to human factors and human influences and anthropogenic influences.

So as we dig into the history of climate science -- and I'm going to take a slightly different approach than Dr. Allen, but I think it will compliment the approach he took.

I think the IPCC report are both a tremendous resource and a great way to just watch how things have evolved and changed over the past 30 years, and how scientific uncertainty and confidence has changed, and how the scientific process functions.

So first let me talk about the IPCC conclusions concerning human influence on climate in the various reports.

In the IPCC AR5 actually tracks through how their findings have evolved each year. So 1990 was the year when the IPCC issued its first assessment. So it's two years after it was formed. And it's typically abbreviated FAR, so I'll sometimes refer to this 1990 report as FAR.

And it conclude based on the best science available at the time, quote:

"The size of this warming is broadly consistent with predictions of climate models, but it is also of the same magnitude as natural climate variability. Thus the observed increase could be largely due to this natural variability;

alternatively this variability and other human factors could have offset a still larger human-induced greenhouse warming. The unequivocal detection of the enhanced greenhouse effect from observations is not likely for a decade or more," close quote.

So, they believed there was a warming trend. They were able to conclude that. They understood that human activity, including the burning of coal, oil and natural gas increased the concentration of CO2 in the atmosphere.

But at that point, they concluded it was not possible to link the two. And as you'll see they correctly predict that it would take about a decade before this group of thousands of scientists from around the world could make that sort of finding.

1995 came the second assessment report known as the SAR.

It concluded, quote:

"Our ability to quantify the human influence on global climate is currently limited because the expected signal is" -- and we heard Dr. Allen talk about signal -- the expected signal is still emerging from the noise of natural variability, and because there are uncertainties in key factors. Nonetheless, the balance of the evidence suggests -- suggest that there's a discernable human influence on global climate. Simulations with coupled atmosphere, ocean models have provided important information about the decade to century time scale, natural internal climate variability," close quote.

So the message from the IPCC is we've made advancements. We've learned more since 1990. And that human -- or it's the data suggesting a discernible influence of human activity. But it's only starting to emerge from the noise of natural variability in light of some of the uncertainties in key factors.

So that's in 1995.

The next report is the Third Assessment Report, and that rolled in in 2001. And, again, we've seen advancements in the degree of certainty or confidence that the IPCC has. And here's what they say in 1991.

"There is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities. There is a longer and more scrutinized temperature record and new model estimates of variability. Reconstructions of climate data for the past 1,000 years indicate this warming was unusual and is unlikely to be entirely natural in origin. The warming over the past 100 years is very likely unlikely to be due to internal variability alone," close quote.

And the IPCC alternately talks about natural variability and internal variability. Basically, they mean the same thing. When they say "internal variability," they are talking about natural, natural factors other than human activities.

So in 2007, AR4 issued the fourth report. And this one is known as AR4. And the IPCC won a Nobel Prize for this in connection with its work on this.

And the AR4 is more definitive, and it's I think viewed as a more definitive assessment by the scientific community.

The AR4 finds that:

"Most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations.

"Discernible human influences now extend to other aspects of climate, including ocean warming, continental-average temperatures, temperature extremes and wind patterns."

Then, as I mentioned earlier, we have AR5, the most recent report from the IPCC.

And it concluded, among other things, that, quote:

"It is extremely likely that human influence has been the dominant cause of the observed warming since the mid-20th century."

So we see how the arc, the conclusions have evolved through the years, beginning in 1990 through 2013. And as I mentioned, AR6 will be coming in 2021.

And I have another quote displayed for the Court that the AR5 concludes that these emissions are driven and increases are driven largely by economic and population growth resulting in increased burning of fossil fuel, like coal, oil and natural gas.

And quoting, quote:

"Globally, economic and population growth continued to be the most important drivers of increases in CO2 emission from fossil fuel combustion," close quote.

And you'll see, Your Honor, I'll come back to this. But in the AR5 report they don't say that it's the production and extraction that is driving increases. It's the way people are living their lives, the way society it's developing economic and population growth. I'll come back to that.

I alluded to this in my opening. The IPCC and AR5 really articulates a view in its evaluation of potential policy options for addressing climate change in a very consistent way.

It says -- and here's the quote in AR5. Says:

"Climate change has the characteristics of a collective action problem at the global scale."

And the Court in its remand ruling gave a nod to this concept:

"Because most greenhouse gases accumulate over time and mix globally, and emissions by any agent, e.g. individual, community, company, country, affect other agents. International cooperation is therefore required to effectively mitigate greenhouse gas emissions and address other climate issues," close quote.

So with that as a predicate, now I would like to go back in time with a little more history.

The notion that we know of today, that we have today of a dynamic changing climate that can shift is relatively new in terms of human understanding.

For more than a thousand years dating back to Aristotle, philosophers and scientists viewed the climate as a static thing that really just depended on where you were on the globe.

So I have up on the screen a map from -- I think from it's from Spain -- from 1575 that reflects Aristotle's concept of the climates. And he kind of came pretty close. He has at the top we have five different climates. The top and bottom are cold and zones became warmer towards the equator.

And because people believed that climate didn't change and it was just based on where on the Earth you lived, early climate study focused on local efforts to understand the weather and to assist in decisions about where to live, what to plant, just how to live everyday life.

There are also early cloud records. And these are from the Ming Dynasty. Just records of what the cloud patterns were. And there were early records of temperatures. The temperatures started being recorded when the model thermometer was invented in the 1600's. And the Fahrenheit scale was developed in the 1700's.

And I particularly like this. Thomas Jefferson has to be one of the most amazing multi-taskers in the world history, because these are temperature records that he recorded during the second constitutional convention, including on July 4, 1776, what the temperature was then.

And so temperature records were being kept by people, and then thermometers were developing. So on July 4, at 6:00 A.M. the way I read this it was 68 degrees Fahrenheit.

And this was still during the little ice age. So Jefferson was doing many things at this time.

So climate science during this period was really about observing temperatures and trying to predict the weather and those sorts of things.

But that said, there are some early records of efforts to understand global climate. And one of the first was from Edmond Halley, of Halley's Comet fame in 1686. He theorized that Trade Winds were generated when sun heated the air near the equator, and then the air rose, and then that forced denser air from higher altitudes to rush in.

This map on the slide shows the directions of Trade Winds across the oceans. This explanation proved to be wrong. But the concept of atmospheric circulation in the climate system and the energy transfer system is still a fundamental feature of climate science.

In fact, it's really at the core of it. The Court asked about the ice ages. And I think it was a great way to focus us, in part, because the focus of climatology really began to change when scientists and geologists start to look at the ice ages.

When they found that ice had once covered large portions of the Earth that upended the notion that climate was static. So there was a different climate at some point earlier.

So much of the basic science about climate came out of the efforts to understand the ice ages.

I'm going to show you a couple of charts here. And they really show the patterns of heating and cooling over time.

These are from the first assessment report from the IPCC. The top graph shows the cyclical patterns of temperature change over hundreds of thousands of years, including patterns of periodic heating and cooling, some of which were cold enough to be ice ages.

And then, the bottom graph shows the history of temperature over the last 1,000 years showing the temperature drop that created the most recent cooling period which the Court also asked about, the little ice age.

And then, you also see the medieval warming period that preceded the little ice age. And then, the little ice age ended in 1850. And I'm going to come back to that.

Dr. Allen talked about this a bit, but just as a prelude the causes of the ice ages, there's still some uncertainty, some disagreement. But scientists believe that they are triggered by the cyclical changes in the earth's orbit around the sun Milankovitch cycles.

In addition, I think Dr. Allen touched on the various feedback loops, the Albedo Feedback Loop where as more as ice and snow build up, Earth reflects more sunlight. The ice doesn't melt. It grows. Makes the Earth even cooler.

John Croll described that in 1875.

THE COURT: Maybe you know the answer. So because it gets worse and worse, right, it feeds on itself. Whatever, what was it that busted us out of that cold spell and allowed the ice to melt away and to -- what happened that reversed that terrible trend?

MR. BOUTROUS: As I understand it from the IPCC reports and some of the history, the process started to reverse. So the Milankovitch cycle, the orbit returns, so the Earth was getting more sun. Then that started to melt the ice and snow. The feedback loop reversed itself. So now you had less sun being reflected back, more being absorbed. The Earth started to heat.

And the last component of it was the IPCC noted that their research shows that during the ice ages the CO_2 levels had dropped as things got colder, once the first, the other two features, the orbit and the Albedo, which is the reflective capacity of the snow on the Earth and ice.

Then, the C02 started to rise back up. That created warming and that's how we --

THE COURT: What caused the CO_2 to go up?

MR. BOUTROUS: I think just the fact that as the warming that occurred because of the change in the orbit, that gradually caused CO_2 to increase. And I think it's AR4 that talks about this.

That they just detected that during the ice ages there was this drop, and then when things started to warm up CO2, there was more of it just coming into the air because of the natural functioning of the atmosphere.

THE COURT: Let me ask you a question. The other side, too. I went to -- just letting you know I got interested in this, so I went back to look at Al Gore's movie called "An Inconvenient Truth."

MR. BOUTROUS: I did, too.

THE COURT: How about that? You did? You looked at it? Okay. All right.

So at one point he has this -- kind of that chart of when the ice ages were, and then he superimposed onto that samples of the carbon dioxide levels that they had been able to reconstruct over the eons of time from, I think he said, ice core samples.

And it seemed to be a pretty good match. In other words, when the CO2 levels were extremely low, then we were in an ice age. And then, when the CO2 levels -- so do you know? I may not be remembering it right. But I wondered what your view of that, that exercise was.

MR. BOUTROUS: Yes. I mean, I can't specifically comment on that, but I do remember that. And I think what I can go back to the IPCC report, and I'll just read you a quote from the AR4.

Here's what it says:

"Although it is not their primary cause, atmospheric carbon dioxide also plays an important role in the ice ages. Antarctic ice core data" -- I think maybe this is what the doctor was referring to -- "show that CO2 concentration is low in the cold glacial times, and high in the warm interglacials."

So I think just as part of the natural process CO2 is very low. And this is what they get from the these core samples. And then, has things come back to life, so to speak, it just naturally starts to increase.

And as the Court knows, a certain level of greenhouse gas effect is required for us to survive and to have it be warm enough so we can live.

THE COURT: I read somewhere that if we had no carbon dioxide it would be too cold.

MR. BOUTROUS: Exactly.

THE COURT: And we would all die --

MR. BOUTROUS: Exactly.

THE COURT: -- a thermostat function.

MR. BOUTROUS: Yes. And, in fact, that's what I believe Fourier, who Mr. Allen mentioned -- and I'm going to talk about him briefly, too -- that he did the calculation. And just based on the math he said something, the atmosphere must be having some sort of warming effect, otherwise we wouldn't be here.

So these are -- Arrhenius, who you'll hear from me about it again and who Dr. Allen -- really was an early -- he really was focused on CO2. And I'll talk about him more on greenhouse gases.

So the little ice age, Your Honor -- Your Honor, again, I was glad you asked the question about it.

If we go to slide 21, it's very interesting. It went from 1450 to 1850. Scientists do not fully understand or entirely agree on the exact causes, but the leading theories are that it resulted from low solar activity, so the sun's intensity was reduced during this period, and high volcanic eruptions, plus a small drop in the amount of greenhouse gas in the atmosphere.

Volcanic eruptions, Your Honor, have a cooling effect because they inject particles into the atmosphere that then block the sunlight from reaching Earth. And so they have a cooling effect. They increase the amount of sunlight reflected back into space by the atmosphere.

THE COURT: Can I quiz you on that now?

MR. BOUTROUS: Yes.

THE COURT: I understand the volcano part. I can see that. I can see a small drop in greenhouse gases would have that effect.

But the solar thing, I want to question you on that.

My understanding for a long time has been there's this 11-year sunspot cycle that goes on 11 years. And it's just like clockwork with small variability.

But that has been uniform since they started making records more than 150 years ago about the sunspots. So what -- you're talking about a 400-year period here. Right? So what did the sun do? What happened to the sun that caused it to emit less energy for 400 years?

MR. BOUTROUS: The IPCC, which I'll go back to, talks about what they say are natural forcings. I don't think --

THE COURT: Natural what?

MR. BOUTROUS: Natural forcings. So things like this where that the sun will sometimes reduce or intensify its output of radiation.

They don't really explain or have a particular, you know, explanation for when and why it's going to do that. As I am standing here right now I can't recall. But I'll go back and take a look, Your Honor. It just happens.

THE COURT: Does it happen every 400 -- how often does it happen?

MR. BOUTROUS: I don't think there were cycles that they have identified. But let me go back and take a look because I think it's a very good point, and it's important, you know, in some of the analysis that he -- looking forward, when I come back to that. The IPCC, the scientific consensus is, you know, assuming that doesn't happen in the future, i.e., that there's an intensifying or reduction in solar energy.

So I'll put a marker on that and may come back with a supplement, probably highly-technical, response on that point.

THE COURT: Okay. How cold did it get in the little ice age? Do we have any information about that?

MR. BOUTROUS: Well, it's cold enough. Here we have, you know, people. The Thames froze. And it was cold enough to survive. But in terms of -- and it was the northern hemisphere, but much colder in terms of actual temperature. And I can get you the actual data on that, as well.

The focus on -- the Court also asked after the little ice age ended, the sea level rose about a foot since 1850 when it ended.

This was a large like academic study, the Ice Age Inquiry. I think led to important advancements in climate science. But a big breakthrough, I think, came as a result of World War II in military research.

World War II prompted, I think, some significant breakthroughs, and it was a turning point for climatology.

Both sides during the war recognized that the weather and climate were important for military operations. And so the U.S. Government funded the training of thousands of military meteorologists. Basically, an army to conduct basic climate research. And the effort ultimately paid off.

I'm sure as the Court knows on D-Day a German meteorologist got it wrong. They thought that storms would prevent an invasion of Normandy. Normandy in June of 1944, while the allied scientists correctly predicted a short break that allowed the invasion to happen.

That, in turn, immediately after World War II resulted in an expansion of climate science funded in significant part of the U.S. Office of Naval Research and other military branches.

I thought the Court would find this interesting, that that military research, if you look at it, led to the development of several aspects of climate science that really go directly to the issues we're talking about today.

For example, discovery and development of radiocarbon dating as an offshoot of the Manhattan Project, which allowed scientists to estimate how much CO2 has recently been added to the atmosphere by the burning of fossil fuels.

Another one: Understanding how infrared waves move through the atmosphere as part of research into heat-seeking missiles. And, obviously, that science goes to, you know, why the infrared waves are captured by CO2 molecules, and, in turn, heat the Earth.

And then, deep ocean circulation, that was part of research into the disposal into the ocean of radioactive bomb debris. And that helped them determine how the ocean absorbs carbon and why the oceans have not absorbed all the excess CO2, which, as Dr. Allen has noted has been an issue.

Throughout the Cold War the U.S. Government has funded a number of nonmilitary research organizations, like NOAA, the National Oceanic and Atmospheric Administration.

NCAR, the National Center for Atmospheric Research, which continues to operate today.

And then, in 1965 President Johnson made a statement sort of in the middle of this about in his message to Congress based on the Presidential Science Advisory Committee Report of the same year.

And he said, quote:

"This generation has altered the composition of the atmosphere on a global scale through radioactive materials and a steady increase in carbon dioxide from the burning of fossil fuels."

So these building blocks of climate knowledge were being assembled. And as I'll discuss in a moment, it was during this period that scientific knowledge about climate change began to grow exponentially.

There was literally an explosion, Your Honor. If we look at the publications that were put out, this is a graph I'm about to put up from a 2001 study by Gerald Stanhill. And it shows how the volume of scientific literature on climate grew from the 1800's to 2000.

And note, Your Honor, this is on a logarithmic scale, so it shows -- truly, I knew I was going to get to use that.

And so it looks like it's kind of, you know, linear, but it's actually --

THE COURT: I understand. The one on the left going up is base-10 logarithmic scale.

MR. BOUTROUS: Exactly. And it's really -- the explosion has continued. Another study from 2011, the solid lines shows the increase in published climate change articles between 1991 and 2010.

The authors of this study found that more than 110,000 scientific articles about climate change published between 1991 and 2010. And more than half of those articles were between 2006 and 2009. So 55,000 articles in that period.

That's why I thought, you know, the IPCC reports and the scientific consensus embodied in those were really a great place to focus principally today. And but notwithstanding all that, the work is continuing. More discovery and theories are out there. And then, we have the AR6 coming in 2021, as I mentioned.

The IPCC isn't the only organization that collects and reviews climate research. The Court may have heard about the issuance of the report from the United States Global Change Research Program.

It has issued four national climate assessments starting in 2000. They involve a number of different U.S.

Government agencies, some 13 agencies contributed to the most recent report which came out in 2017.

And they focus on the state of climate science with respect to the United States. So they are focused on the United States.

They, in turn, rely substantially on the IPCC reports that I'm principally relying on, that I'm relying on today.

So, with that, I'd like to get into -- just go back in time a little bit more to fill in a couple of the other areas of history that Dr. Allen alluded to, but didn't discuss in detail.

The climate scientists have identified three fundamental processes that can change global temperature. Changing them out of incoming solar radiation. And that can happen based on variations in the Earth orbit or variances in the sun's output, changing the fraction of sunlight that is reflected back into space when the Earth is brighter or when there are particles from volcanos injected into the atmosphere.

And then, changing the fraction of infrared radiation from the Earth that is absorbed by greenhouse gases in the atmosphere.

For obvious reasons I'm going to focus principally on the historical development of the science there.

As Dr. Allen mentioned, Joseph Fourier in 1824 first determined that the amount of energy reaching the Earth from the sun was not enough to explain the earth's warm temperatures.

He concluded that the atmosphere had to be keeping the Earth warm. Then, 35 years later, Irish scientist, John Tyndall, through a series of lab experiments, determined that water vapor and CO2 in the atmosphere can cause the greenhouse effect.

And then, it was in 1896 that Svante Arrhenius used calculations of CO2 emissions from factories burning coal to conclude that, like volcanos, but on a tiny scale, these factories could increase the Earth temperature by increasing the concentration of CO2 in the atmosphere.

THE COURT: What did he do? He made some specific predictions. Right?

MR. BOUTROUS: Yes.

THE COURT: What were those predictions?

MR. BOUTROUS: Well, he predicted that, as you know, the more coal -- and this is one of the charts we had earlier -- the more coal that was burned and the more CO2 that was injected into the atmosphere based on human activity, that could have a warming effect.

And so you would think with those three the building blocks would have been laid for this entire world climate scientist. But there's a missing chapter from Dr. Allen's story. He referred to it, but there was another scientist that rolled around four years later, Knut Angstrom. And he was another Swedish scientist.

In 1900, he purported to disprove Arrhenius' theory and his prediction that changes in CO_2 could impact global temperature.

He used lab experiments, spectrographs, and concluded that any infrared radiation that would be absorbed by CO_2 was already being absorbed by the much larger concentration of water vapor.

In other words, the CO_2 was duplicative and irrelevant. Water vapor was already absorbing all infrared radiation.

And you'll see from this quote from the Monthly Weather Review put out by the U.S. Department of Agriculture in 1901, they were pretty much giving their battle, the wind to Angstrom.

They said, quote:

"The remainder of Angstrom's paper is devoted to a destructive criticism of the theories put forth by the Swedish chemist, S. Arrhenius, in which the total absorption of CO_2 is quite inadmissibly inferred from the data which include the combined absorption of CO_2 and the vapor water," close quote.

And I think Dr. Allen mentioned the papers in the 1930's, I think, sort of touching on this issue.

It appears that Angstrom's conclusion rejecting Arrhenius' theory remained the accepted view for more than 50 years.

And in 1951, Your Honor, the American Metrological Societies Compendium of Meteorology noted, quote:

"Arrhenius saw in this cause of climatic changes, but the theory was never wildly accepted and was abandoned when it was found that all the long-wave radiation absorbed by CO2 is also absorbed by water vapor," close quote.

THE COURT: What year was that statement?

MR. BOUTROUS: That was 1951 from the American Meteorological Society. But the '50's turn out to be a period of significant advancement where Arrhenius comes back, back into favor.

THE COURT: Wait a minute. Before you -- you jumped over 1938. Right? Who was in 1938?

MR. BOUTROUS: 1938? Now, you are going to stump me.

THE COURT: Maybe I'm not remembering right, but wasn't a guy named "Callendar," and they even called it the "Callendar Effect," not like the calendar, but C-A-L-L-E-N-D-A-R.

And he did the little line, the same line about CO2 going up, and also said that it was causing the Earth to get warmer. And this was a formal scientific paper. Right? I mean, so that seems like there was somebody who was continuing to keep the story alive that CO2 was a bad thing.

MR. BOUTROUS: Right. Yes.

THE COURT: Well, maybe not a bad thing. Just going to get warmer. I think he said it was actually a beneficial thing. It was going to make everything warmer and we wouldn't have to worry about the ice age again. But, nevertheless, it was getting warmer.

MR. BOUTROUS: You are right, Your Honor. I didn't mean to suggest that there were no other papers out there.

THE COURT: But you said that by 1950 that this guy Angstrom, his theory held sway, and that even in 1950 it was still holding sway, so wouldn't it be more accurate to say there were two views?

MR. BOUTROUS: Perhaps, Your Honor, because I'm going to get to the point at the end of the day it really is going to prove a point about science.

But Callendar agreed with Arrhenius, but it wasn't viewed, as far as we can tell, as the accepted view. The accepted view was that Arrhenius was wrong.

But here's where the stories turn.

THE COURT: Okay.

MR. BOUTROUS: And, you know, science is about debating things because I think Dr. Allen referred to Gilbert Plass. And I think, for example, in 1950 Benedict and Plyler came in to say that they discovered that CO_2 can absorb different wavelengths of radiation on CO_2.

Angstrom thought that they were be absorbing the same type of infrared radiation, therefore CO_2 is duplicative. Among other Benedict and Plyler opinions said, no, they have more powerful spectrographs. They could see the different wavelengths and determined that, no, CO_2 was having its own effect as a greenhouse gas.

THE COURT: I'm sorry.

MR. BOUTROUS: Yes.

THE COURT: Say this Benedict, what year was that?

MR. BOUTROUS: Plyler? That was in 195 --

THE COURT: One.

MR. BOUTROUS: Fifty-one.

THE COURT: What's the conclusion that they reached?

MR. BOUTROUS: They reached -- they refuted Angstrom's theory. They determined CO2 is absorbing a different radiation length than water, therefore it was a greenhouse gas that was having an effect.

THE COURT: All right. So we're back. At least in '51 we're back to Arrhenius is correct.

MR. BOUTROUS: He's back. He's back. And others then picked up on that theory. And that's the theory that has held today. But I think the point I really wanted to make is that's how science works. It's trial and error. It's experimentation. Scientists debating each other.

It's cumulative. It is self-correcting. And I like the book Brilliant Blunders by Mario Livio that sometimes a big mistake can lead to a big discovery.

He says:

"The road to discovery and innovation can be constructed even through the unlikely path of blunders," close quote.

And so sometimes discoveries are unintentional. Sometimes they come from questioning other scientists' views. And it's really part of the scientific process.

Another significant development in the '50's came from Revelle and Suess. Dr. Allen talked about Revelle. I want to give Suess his day in the sun here.

In a related finding, they determined that -- they looked at whether the ocean could absorb all the excess CO2. And this was in 1956. They determined that while the CO2 mixes rapidly in the upper layers of the ocean, it can take centuries to mix with the deeper parts of the ocean.

And at that point scientists began to really question the notion that the oceans could eliminate all the excess CO2. So it was going somewhere else. It wasn't being absorbed in the ocean.

And then, Keeling came along, ended his study, his family's study with the Keeling Curve in Mauna Loa, and determined that the amount of CO2 in the atmosphere was increasing and that the excess was not being absorbed in the atmosphere.

Picking up on sort of how things developed, not necessarily when there's a focus on the particular subject matter, greenhouse gases. In the early '60's, I think one of the Court's orders asked about the ozone. So here's a connection that I found interesting.

Congress instructed NASA to study the impact of the ozone layer of proposed supersonic airplanes and the space shuttle. And there was concern, the Court will recall, that the exhaust could destroy the ozone.

And that led to an examination of CFCs, chlorofluorocarbons, and their impact on the ozone layer. And ultimately those synthetic chemicals were determined to be greenhouse gases, the chlorofluorocarbons. And there was a showing they could have a significant greenhouse gas effect, greenhouse effect. It also shows that they did have a significant effect on the ozone layer.

And they were then banned in 1987 by the -- they actually -- the Montreal Protocol, they were limited, and then banned in 1996.

But the examination as greenhouse gases led to other discoveries of synthetic chemicals that could have a greenhouse effect. And I just put up on the screen a number of examples.

The one that I wanted to just point out is the HFC, hydrofluorocarbons. Those were the chemicals developed in the 1980's to replace CFCs, and they turned out to be greenhouse gases, as well. So there are other synthetic greenhouse gases out there.

THE COURT: Help me understand the ozone part. Is it CF -- give me the code word again.

MR. BOUTROUS: CFC's.

THE COURT: CFC's. All right. So I definitely remember that period when we were alarmed over that. And in some of the reading I did it seemed to me that there was a suggestion that the ozone layer in its natural state reflects back some of the sunlight from the sun so that it tends to cool the Earth. Am I right about that?

I know the ozone layer also has other -- it keeps ultraviolet radiation from coming through. I believe that's true.

But what does it -- does it also have an effect of reflecting back sunlight that would otherwise hit the Earth and therefore make it even warmer? What's the answer to that?

MR. BOUTROUS: I don't know the answer to that, Your Honor. I know that it does have an effect in terms of a warming effect and the other effects. But I don't know. You know, you asked about carbon dioxide and whether it's reflecting sunlight back. It's transparent to the visible light. But I'm not sure with respect to the ozone layer's cooling effect in that regard.

And, again, I can follow up.

THE COURT: All right. So but CFC's also act as a -- like carbon dioxide as something that traps heat on the Earth?

MR. BOUTROUS: Yes. They have a powerful greenhouse effect.

THE COURT: Now, in terms of which one is more problematic right now, is it carbon dioxide or is it CFC?

MR. BOUTROUS: Carbon dioxide. Now, synthetic with

CFC's having been banned, they are not having as much of an effect now.

But there are other synthetic greenhouse gases, but they are not having the effect, the degree to which carbon dioxide and other greenhouse gases are.

THE COURT: Thank you.

MR. BOUTROUS: Thank you.

So with that, Your Honor, I think I'm going to maybe end this portion of my discussion really about in terms of where science is now with the concept of modeling and projecting into the future.

And the IPCC AR5, and other reports, talk about modeling and so at the same time scientists were making these discoveries, the modeling tools became more powerful and more complicated. The models began to allow scientists to simulate interactions between components of the climate system over time.

And computers in the 1970's were becoming more powerful. They used algorithms to represent the interaction of different elements of the climate system, like the atmosphere, land surface and ocean and sea ice.

And you see this chart from AR5 shows that with each iteration of the IPCC Assessment Reports, climate models added more components over time. And those have become increasingly complex.

That can make the modeling more powerful. You can try to -- you kind see more. You can try to understand more. But because it's an attempt to represent things happening in the real world, the complexity can also bring --

THE COURT: Was there a model that you think is reasonably accurate?

MR. BOUTROUS: Well, I think that, you know, we, Chevron, accepts the approach that the IPCC uses, which involves a bunch of different models. And I'm going to talk about that if I segue into part two. And, in fact, I'll show you and give you an example.

They say there's no one best model; that different models can do different things better, and they haven't found one that does it all.

So they run many, many models on different emission scenarios, and I'm going to turn to that.

THE COURT: Kind of like the hurricane models that each one predicts a slightly different path?

MR. BOUTROUS: Right. Exactly.

THE COURT: Okay.

MR. BOUTROUS: And so, and then the IPCC looks, and the scientists get together, you know, and try to come to a consensus and make determinations about the likely range, for example, of temperature increase or sea level increase based on this table of models.

And I'll show you that in a minute. The point I want to make here is that the IPCC itself says:

"Climate models of today are, in principle, better than their predecessors. However, every bit of added complexity, while intended to improve some aspect of simulated climate, also introduces new sources of possible error," close quote.

So, you know, you can do certain things. But then you're -- you know, you're limiting other features. And so the IPCC points to that and grapples with that as it makes its assessments.

Let me go to the next slide before we go --

THE COURT: Don't you think it's amazing that that guy Arrhenius --

MR. BOUTROUS: Yes.

THE COURT: -- with no models, no computers --

MR. BOUTROUS: Yes.

THE COURT: Just the back of an envelope and pencil and paper could have made that prediction which even today sounds pretty reasonable, doesn't it? That if you doubled the amount of carbon dioxide from those levels that -- what was it -- 4 degrees Centigrade I think the Earth would go up?

That's in the ballpark of what I think these models are saying. Right?

MR. BOUTROUS: These scientists are brilliant. I mean, again, when you look back what they were doing, they were just coming up with this themselves and making a hypothesis and testing it. So I --

THE COURT: But he was just one guy.

MR. BOUTROUS: He was just one guy.

THE COURT: One guy in an early age and using his brain and some data, but not -- but just thinking it through. You have to admire that.

Okay. I'm sorry. Go ahead.

MR. BOUTROUS: Yes. No. And now this is a good time. One guy back in 1896, and now we have these models that can do a lot. And this is just for illustration, and I'll talk about it more in the next segment.

But this graph from AR5 shows model projections for the Earth temperature through 2050. And just to give the Court a feel for it, the solid black line shows the observed temperatures, so that's what actually happened.

The colored lines show the modeling estimates based on various emissions inputs. And so you'll see it says those are the RCPs. So the RCP 2.6 is the lowest emissions scenario they are looking at, they are assuming.

And then, RCP 8.5 is the highest emission scenario. They are assuming the highest level emissions going forward.

And then, this goes to the Court's earlier question. They ran multiple different models that had different factors included in them at each scenario.

So 42 models for 4.5, 39 models for RCP 8.5. And that's -- then you see this tangle of projections going into the future.

Based on the models and the mission scenarios the range gets wider as it gets farther out in the future, reflecting, I think, just the common sense notion that it's harder to predict things as they go into the future.

THE COURT: Just so we can -- so the model that would be the most conservative in year 2050, if it's correct, what does that mean? The temperature would go up by about 1 degree in Centigrade?

MR. BOUTROUS: Well, you know, it depends, Your Honor. In fact, I'm going to show you how the IPCC put that. But, yes, if you just looked, if you picked one of those lines, and then you picked the year, you'll see some of the RCP 2.6 models, they are at different places because the model is different in terms of the factors they were using.

THE COURT: Anomaly:" means difference. Right?

MR. BOUTROUS: Yes.

THE COURT: That is what that means?

MR. BOUTROUS: Exactly.

THE COURT: Compared to what year? What year are we --

MR. BOUTROUS: So what year did you mention, Your Honor? You said --

THE COURT: 2050 at the very far right. But what is the base year that we're comparing it against?

MR. BOUTROUS: The base year here -- and, Your Honor, I think you're right.

THE COURT: Must be 1986.

MR. BOUTROUS: Yes.

THE COURT: I'm not sure.

MR. BOUTROUS: I've got that here for you, Your Honor but I think it would be -- as you pointed out, the lowest one would be about a .5 degree increase as I look at it.

THE COURT: I see. I see. Okay. And then, the highest would be almost 2.5.

MR. BOUTROUS: Right.

THE COURT: Centigrade.

MR. BOUTROUS: Yes. And then, I'll return to this in the next segment to give you an example of what the IPCC does to try to make an estimated range of temperature increases based on these models.

THE COURT: Okay. You want to stop there? You've used an hour. So you have an hour left, and then we have 30 minutes for the Plaintiff side left. And we'll take a break now so the public can use the facilities.

Where is Dr. Allen?

I want you to know that I think you are right about the logarithm thing. And I want -- on base two that would definitely be a logarithmic scale.

All right. We'll see you in about 15 minutes. Thank you.

MR. BOUTROUS: Excellent. Thank you.

THE CLERK: Court is recess.

(Thereupon, a recess was taken.)

THE CLERK: Please remain seated.

THE COURT: All right. Back to work. Please remain seated. Okay.

So let's finish your half. So you have another hour to go, and then we will return to the Plaintiffs' side for the finale.

MR. BOUTROUS: Okay.

THE COURT: But before I go, while I have you here, Mr. Boutrous, is your side going to consent or object or have any problem with those amicus submissions? There were two that came in, and I received a paper from Plaintiffs that they have no objection. So if you don't have any objection, then I'm going to just approve it.

So do you have any objection?

MR. BOUTROUS: We have no objection, Your Honor.

THE COURT: All right. Then, I will eventually get an order out approving the amicus submissions.

Okay. Please go ahead.

MR. BOUTROUS: Thank you, Your Honor. I'm now going to move to part two of the tutorial, which the Court asked us to address the best science now available on global warning, glacier melt, sea rise and coastal flooding.

I'm going to walk through those topics basically in order.

Just as in part one, I'm going to be relying on the AR5 from the IPCC, and, in particular, I will be citing a Working Group I report on the physical science basis of climate change.

THE COURT: Okay.

MR. BOUTROUS: The first topic I'm going to discuss is global warming. And the Court's already on top of this. I can tell from the questions. But just a couple of terms.

So global, when we talk about global warming and temperature, there's no one global temperature. And scientists have developed "global" means "surface temperature," which in laymen's terms an average of the temperatures around the world.

And it's not measured directly. It's done by estimating and using measurements at various places.

So we will all be using that term a lot during this segment.

As the Court also already noted, the IPCC -- maybe we'll go to slide three -- does use a baseline. So in every slide here are the baselines. And that means I have them in here. I have them for our convenience. And it's the state against which the change is measured, as the IPCC points out.

So on this chart which I'm going to talk about in a second, it's from AR5. Anomalies are being plotted on the graph with respect to the baseline of 1881 to 1980.

THE COURT: No, this goes back 2000 years. Am I looking at the wrong chart?

MR. BOUTROUS: Yes. This is the temperature variations during the last 2000 years.

THE COURT: All right. Explain that one to me.

MR. BOUTROUS: Sure. So this figure is from Working Group I. It's in the -- it is, as it is titled. That's the title from the IPCC. The dotted line represents the baseline, which is the average global temperature from 1881 too 1980.

So they are comparing those other temperatures to that baseline global average, global mean temperature from 1881 to 1980.

THE COURT: The dotted line?

MR. BOUTROUS: Yes.

THE COURT: On mine it looks like this a bunch of red dots that go back to 1600.

MR. BOUTROUS: So, Your Honor, if we're looking at the same chart, so it's the chart titled: "Temperature variations during the last 2000 years."

THE COURT: Right.

MR. BOUTROUS: And I think he has got the --

THE COURT: Curser. Go ahead.

MR. BOUTROUS: So if you look at the 0.0? That is the baseline. So then the temperatures are being compared against that baseline, 1881 to 1980, throughout that period. It really starts at, you know, 500.

THE COURT: It looks like way back in the medieval era. Right?

MR. BOUTROUS: Yes.

THE COURT: The temperature was higher than the baseline; is that right?

MR. BOUTROUS: Correct, the medieval warming period.

THE COURT: Then, starting around 1300, 1400 it dropped.

MR. BOUTROUS: Correct, the little ice age.

THE COURT: Little ice age. And then, it stayed -- looks like, according to your chart, it stayed below the mean until about 1900? And then, it is skyrocketing up. Right?

MR. BOUTROUS: It stayed below the mean. And then, around 1900 in 1901, I think temperatures start to rise again.

THE COURT: But it's pretty fast, it's rising, not just a big rise. But okay. But you said something about a dotted line that went back on my -- the one I'm looking at, the red dots go back to 1600.

MR. BOUTROUS: Right. You are right. My fault. I was just referring to the dotted lines that reflected the base line.

THE COURT: The dashed line.

MR. BOUTROUS: Yes, exactly. Just to pick up, the colored lines and the black lines indicate baseline using different data sets. So the black lines on the figure are instrument data. So that's measured.

And then, the colored lines and dots represent various reconstructions of the past.

THE COURT: Okay.

MR. BOUTROUS: So that's that figure. And let me go into a little bit more recent period, 1850 to 2012. And, again, 1850 was the end of the little ice age. And this is really the point the Court was just making. The IPCC AR5 concludes that:

"Since 1901 almost the whole world has experienced surface warming. Warming has not been linear; most warming occurred in two periods: Around 1900 to around 1940 and around 1970 onwards."

And so, again, this -- each of the colored lines shows the average global temperature anomaly based on a different dataset from 1850 to 2012. And the baseline is the global means surface temperature from 1961 to 1990. So they are comparing against that.

The next slide is basically the same slide, I believe. But if we look at the 20th century warming, the early period, Your Honor, from 1901 to 1950, here's the conclusion of the IPCC.

Quote:

"The early 20th century warming is very unlikely to be due to internal variability alone. It remains difficult to quantify the contribution to this warming from internal variability, natural forcing and anthropogenic forcing, due to forcing and response uncertainties and incomplete observation," close quote.

And since I knew you would ask me what caused that warming I thought I would just go with that quote because I think what they are basically saying is that in the early 20th century, while it's unlikely that the climate was functioning -- the warming was caused by the climate functioning in its natural course, internal variability, the IPCC couldn't quantify any contributions to the warming from potential other causes, like changes in the sun or volcanos. That's the natural forcing.

THE COURT: What does "internal variability" mean?

MR. BOUTROUS: That is their phrase for just describing the natural, natural variability in the climate without some event like a volcanic eruption, which is what they call a natural forcing sort of an event.

And then, anthropogenic forcing is human activity like the kind of things we're talking about here.

THE COURT: When was that Krakatoa volcano? Wasn't that about 1880 something?

MR. BOUTROUS: That sounds about right, Your Honor.

THE COURT: So that was supposed to have had a cooling effect. Right?

MR. BOUTROUS: Volcanos generally have a cooling effect.

THE COURT: So part of that downward curve might be -- anyway, but around 1901 it starts to go up. And what this statement is saying to us, if I got it right, is that it's very unlikely to be due to internal. Is that a roundabout way of saying it is due to CO2?

MR. BOUTROUS: They are saying they think something other than just internal variability, natural climate fluctuations.

THE COURT: Well, that would be human. Right? They are saying it must be human, but they are not saying it directly.

MR. BOUTROUS: They are saying, you know, they can't tell. In addition to internal variability there are other natural causes. So sort of, as I said, an event, an increase in the sun's solar power, something.

But, and then, but anthropogenic forcing is human activity.

So they are saying they think something other than natural activities is causing the warming. But they don't have enough data. They are not able to pin that down for that period.

Now, things get different. I'm going to move to the next slide, Your Honor, because here when we get into the more recent period, the period 1951 to 2010, they are able to draw conclusions.

And this is a variant of what I displayed at the beginning. In the second half of the 20th century they analyzed that data and concluded that it, quote:

"It is extremely likely that more than half of the observed increase in global average surface temperature from 1951 to 2010 was caused by the anthropogenic increases in greenhouse gas concentrations and other anthropogenic forcings together."

THE COURT: "Anthropogenic" means "human"?

MR. BOUTROUS: Yes.

THE COURT: Right. Okay.

MR. BOUTROUS: So that's this most, you know -- that period there they are able to make that conclusion.

So since they talked about the anthropogenic increase in greenhouse gas concentrations, Your Honor, I thought I would briefly touch on historic CO2 emissions, just to make a couple of things clear.

So this chart has the historic human CO2 emissions for the United States, China and India from about 1970 to 2010.

They are on different scales, Your Honor. The top chart has China, United States and India. And you'll see that China is increasing. India is increasing. The United States, the emissions went -- leveled off and then dropped down as of 2005.

And the quote I have up there is one I mentioned earlier.

Quote:

"Anthropogenic greenhouse gas emissions are mainly driven by population size, economic activity, lifestyle, energy use, land use patterns, technology and climate policy," period, question mark. Excuse me, quote mark.

And I think it's important when you think about it, as the Court probably is aware, that China is burning more coal than the United States. With the hydraulic fracturing or sometimes called "fracking," that has caused reduced coal burning in the United States and reduced greenhouse gas emissions.

So you see how different energy uses can change and affect the greenhouse gas emissions.

And I said this earlier, I think the IPCC does not say it's the extraction and production of oil that is driving these emissions. It's the energy use. It's economic activity that creates demand for energy. And that leads to emissions, especially due to the importance of having affordable energy sources.

THE COURT: What is the -- the vertical column, I know, measures CO2. Right?

MR. BOUTROUS: Yes.

THE COURT: Is that tons or --

MR. BOUTROUS: Megatons.

THE COURT: Megaton.

MR. BOUTROUS: Megatons per year.

And then, the bottom scale for the world is doing the same thing, but it's on a different scale because the world has more megatons. But it, again, shows the increase.

THE COURT: On the top, this chart comes from the IPCC. Right?

MR. BOUTROUS: Yes. Well, both charts are from IPCC AR5. We took, just so the Court knows, we took the China, U.S. and India and put them all on the same chart, same scale, just so the Court could see it altogether.

THE COURT: One thing that surprises me about this is the U.S. line, while it has gone up, has not gone up that much.

But the China one has gone up dramatically --

MR. BOUTROUS: Correct. And that is because, you know, their economy --

THE COURT: -- and surpassed the USA.

MR. BOUTROUS: Yes. And it really goes to the global nature of this. Their economy has been expanding. That leads to more activities. That creates a demand for more energy. They are burning coal, more coal than the U.S.

The U.S. has been using other sources of energy: Natural gas. That has been one of the contributing factors to the levels you see comparing the United States and China.

THE COURT: On the India graph, there seem to be two lines, an orange one and a green one or something. So what is the point of the two lines?

MR. BOUTROUS: I think those are different datasets, Your Honor. We had all three. So you'll see there are different colors for each. And so they did these analyses using different datasets, and they are pretty comparable.

THE COURT: All right. So go to the one on the bottom? That's worldwide.

MR. BOUTROUS: Yes.

THE COURT: And as of right now, the most recent data -- it's hard to read.

MR. BOUTROUS: I can enlarge.

THE COURT: What is the total, 30,000 31 something? 33? Let's say 30,000.

MR. BOUTROUS: Yes.

THE COURT: All right. So 30,000. So the USA would be what portion of the 30,000?

MR. BOUTROUS: So if we go back up to the top chart, on this graphic from the IPCC it looks like about, you know --

THE COURT: 6,000.

MR. BOUTROUS: Six thousand, 5900.

THE COURT: So that would put us at -- here's where I need Dr. Allen.

Well, what is the percentage of that? 6,000 into --

MR. BOUTROUS: 30,000.

THE COURT: -- 30,000. 20 percent?

MR. BOUTROUS: Yes.

THE COURT: Okay. So the USA is responsible for 20 percent. Is that right, about roughly?

MR. BOUTROUS: Based on your calculations, Your Honor.

THE COURT: Well, I'm asking you. All right. Okay. so still, USA is pretty big. I wonder where Europe would fit in here. Have you done -- where would Europe be? Comparable to the USA? What would it be?

MR. BOUTROUS: We can get you that data.

THE COURT: No, that's okay. All right. Go ahead.

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

So that's historic CO2 emissions.

Let's turn to future temperature projections. And this is sort of where I left off with the modeling discussion. And I think Dr. Griggs mentioned the emission scenarios. I referred to them earlier.

Just to illustrate what they are, this chart from the AR5, is kind of laying out what they are. So the representative concentration pathways are also called, just in shorthand, "The Emission Scenarios."

They reflect less potential future mitigation efforts, such as carbon capture the higher up we go. So if we look at the chart, the black line represents the historic CO2 emissions through 2011.

And then, they start looking out to the future. The 2.6, the dark blue line is considered the lower, the low emissions scenario.

RCP 8.5, the red line, is the high emission scenario.

And then, 4.5 and 6.0 are the two intermediate scenarios.

So as I mentioned, the IPCC runs different models based on different scenarios in terms of the quantity of emissions from human activities.

THE COURT: Here's something.

MR. BOUTROUS: Yes.

THE COURT: How can this be? I got some that are going downward. Some of these projections go down. Right?

MR. BOUTROUS: Correct, yes.

THE COURT: So what assumptions are made that would cause the amount of CO2 to go down?

MR. BOUTROUS: For example, that one, the lowest one, which is RCP 2.6, they are modeling and calculating in different mitigation efforts, such as carbon capture and storage, and other -- that other mitigation efforts will be made as a policy matter. And so they factor that into that.

And then, on the red line they are assuming that those sorts of things won't have been done. And that emissions will go forward.

So then the next chart, you will recall, the next graph, this is, again, from the AR5. And it's the one that I displayed earlier. This is -- I kind of want to walk through what they actually do with it, with the Court's permission.

The various models that are in the parentheses on the left-hand side of the screen and the top, next to the RCP emission scenarios have different factors and different considerations built into them. And there are many, many of these models.

This is the Working Group I from its chapter on near term climate change. And this is just to illustrate how they go through the process of projecting future temperature change.

As I mentioned earlier, the colored lines on the figure are the various model runs, with the solid black line is the historical actual observed temperatures.

And if you -- you'll see that the black line here when it crosses the dotted line it is at the lower end of the bottom end of the projections. So to the bottom end of the tan-colored lines.

And that, the IPCC observed -- and this is the quote up on the side, quote:

"Some models may be too sensitive to anthropogenic forcing," close quote.

So they are saying that the models were assuming a greater effect from human activity on the temperature than turned out to be the case in actual observed temperatures.

THE COURT: All right. Let's -- okay. I think I understand your point. But all right. There's the obvious dark line, black line on the left that says "historical." And then, there's a dashed vertical, but that is hard to see.

But the black solid line continues on a few years thereafter. Right?

MR. BOUTROUS: Yes.

THE COURT: So the squiggly colored lines, are those what the models that existed back at the time of the dashed line, vertical line, what they would have projected?

MR. BOUTROUS: That's what they were projecting, so --

THE COURT: By what point? At the point of the dashed lines?

MR. BOUTROUS: Yes. So as I understand it from the IPCC report, that's what they were projecting from that period, from the dotted line forward.

And then, as it turned out, you see the observed temperatures, what actually happened at least with respect to some of them, the observed temperatures were lower than those models were predicting.

THE COURT: And that was true for how many years? Looks like five years maybe?

MR. BOUTROUS: Yeah. Yeah. Well, really --

THE COURT: Six.

MR. BOUTROUS: -- pretty much going from 2000 to about 2012, really. Almost to the end when you look at that, because I think that's when they are -- this is from -- yeah, really almost the entire time. Some are below. Some of the models do run -- were predicting less.

But it's really from, let's see, 2000. I think it's about 2005 to 2012.

THE COURT: All right. So your point is the models overstate the problem.

MR. BOUTROUS: At least -- at least with respect to that period of time.

THE COURT: And instead of doom and gloom, it's just gloom. But it's still going up.

MR. BOUTROUS: You know, Your Honor -- and, again, I'm just really reporting the way the IPCC has looked at this. And you'll see that the going farther into the future you have the various different models based on different RCP scenarios, kind of going out in the future.

And the other quote I have displayed is again from the IPCC, quote:

"By mid-21st century, the magnitude of the projected climate change is substantially affected by the choice of emissions scenario," close quote.

So, in other words, as a policy matter, but also just as a modeling matter, the more emissions you anticipate, the magnitude of projected climate change is going to be a function, but a function substantially affected by that choice.

So then, the question is: How do they make a prediction?

THE COURT: Is this in the IPCC report?

MR. BOUTROUS: Yes, it is. And we'll give you copies of all this.

THE COURT: All right.

MR. BOUTROUS: It's right out of AR5.

THE COURT: Can you give me color copies?

MR. BOUTROUS: You bet. Absolutely. And we'll give Plaintiffs a copy, too.

So now, just to give you a sense of how -- what they do once they have this data, we'll go to the next slide.

And here this is the chart, the graph that represents the IPCC Working Group I, making a determination based on all that data, all the models, the various scenarios, what's the likely range of temperature from 2016 to 2035?

And so they -- what they do, they added the -- that's the IPCC red box to represent their determination of likely -- to them that's greater than 66 percent -- future increases in global mean temperature.

And I'll just read the conclusion, and then I have a feeling you might have a couple of questions.

So, quote:

"Overall, in the absence of major volcanic eruptions -- which would cause significant but temporary cooling -- and, assuming no significant future long term changes in solar irradiance, it is likely, 60 percent (sic) probability that the Global Mean Surface Temperature anomaly for the period 2016 to 2035, relative to the reference period of 1986 to 2005 will be in the range of .3 centimeters -- Celsius -- excuse me .3-degree Celsius to .7-degree Celsius."

And then, they say:

"(Expert assessment, to one significant figure: Medium confidence)," close paren, close quote.

And that would translate to about .5 degrees Fahrenheit to 1.3 degrees Fahrenheit. So that's their like predicted likely range for that period and potential increase.

THE COURT: Ending in the year 2035.

MR. BOUTROUS: Yes.

THE COURT: Okay. Well, okay. Just a minute. This IPCC, Intergovernmental -- what does the P stand for?

MR. BOUTROUS: Panel on Climate Change.

THE COURT: Climate change.

MR. BOUTROUS: Yes.

THE COURT: And the U.S. is part of that. Correct?

MR. BOUTROUS: Yes.

THE COURT: So that is saying that "likely," meaning more than 66 percent probability that between 2016 and 2035, there will be an increase and it will be in the range of .3 to .7 C.

MR. BOUTROUS: Yes.

THE COURT: Okay. And .7 C is, did you say, one-and-a-half degrees Fahrenheit.

MR. BOUTROUS: 1.3 degrees Fahrenheit.

THE COURT: 1.3. All right.

MR. BOUTROUS: So that's their process. And they have a process for, you know, reaching consensus for analyzing issues. And that's how they -- how they do that and project into the future.

THE COURT: I'm sure you are going to get to it, but let's say that that prediction is correct. So what would that translate to in terms of sea level increases?

MR. BOUTROUS: I'm about to turn to glacier melt and sea level, because you'll see it's a somewhat complex analysis in terms of translating actual contributions of human activity to warming, and then translating that to sea level rise. But I'm about to -- perfect -- it's a perfect segue, Your Honor. Let me start with the glacial melt.

So the Court asked about glaciers. And in addition to glaciers, which are a form of land ice, there are ice sheets. And ice sheets are another type of land ice, obviously, but much larger.

In IPCC's words they are of continental size and the only two are Greenland and Iceland. And this is another graphic from IPCC AR5, to orienting us all. It's shows the glaciers in yellow. You can see on the graphic the ice sheets are in white.

And then, you've got sea ice as the light blue around it.

And Your Court will recognize Greenland in the northern, the top view, and Antarctica in the southern bottom view.

And Your Honor, again, for reference Chapter Four of the AR5 Working Group I goes into great detail on the ice masses.

And so, again, so we've got Greenland at the top, Antarctica on the bottom. Let me start with glaciers, and just give the Court a few of the key findings from the IPCC on glaciers.

First quote:

"The arithmetic-mean estimate of Leclercq, et al, 2011, indicates continuous makes loss from glaciers after about 1850," close quote. Again, was the end of the little ice age.

Another finding:

"Overall, there is very high confidence that globally, the mass loss from glaciers has increased since the 1960's," close quote.

And then, another finding is, quote:

"Anthropogenic influences likely contributed to the retreat of glaciers since the 1960's," close quote.

So that is what they have found in terms of glaciers. And there's a likely effect from human activities since the 1960's. That's glaciers.

And then, if we go to ice sheets of Greenland and Antarctica. Starting with Greenland, the IPCC has found that, quote:

"Over Greenland, temperature has risen significantly since the early 1990's, reaching values similar to those in the 1930's," close quote.

Then, they find, quote:

"There's a very high confidence that the Greenland ice sheet has lost ice during the last two decades," close quote.

Third, they find, quote:

"It is likely that anthropogenic forcing has contributed to surface melting of the Greenland ice sheets since 1993," close quote.

And they also find that, quote:

"Since 2007, internal variability is likely to have further enhanced the melt over Greenland," close quote.

THE COURT: What does "internal variability" mean?

MR. BOUTROUS: Just natural changes in the atmosphere and the temperature aside from human activities, including emissions of greenhouse gases.

Now, let's turn to Antarctica. It's a very different story in terms of the conclusions and the ability of scientists to understand what is happening in Antarctica.

First on Antarctica, and it's the biggest sheet, the IPCC says, quote:

"Overall, there is high confidence that the Antarctic ice sheet is currently losing mass," close quote.

Second, they say, quote:

"There is low confidence that the rate of Antarctic ice loss has increased over the last two decades," close quote.

Third:

"Anthropogenic forcings" -- human activities -- "have likely made a substantial contribution to surface temperature increases since the mid-20th century over every continental region except Antarctica," close quote.

So they are not able to make that determination that there's been a likely contribution to increased surface temperatures caused by human activity in Antarctica.

And --

THE COURT: Why would that be? Why would it be different for Antarctica?

MR. BOUTROUS: In fact, let me go to the next slide.

I think I mentioned that a key uncertainties summary -- and it's very helpful. The reports are pretty easy to navigate. But they have one -- they have three key uncertainties about Antarctica. And this is kind of one that captures it.

So key uncertainties captures the key uncertainties in understanding the climate system and its recent changes.

"In some aspects of the climate system, including Antarctic warming, Antarctic sea ice extent, and Antarctic mass balance, confidence in attribution to human influence remains; low due to modeling uncertainties and low agreement between scientific studies," close quote.

They also, I think, in another spot say that the, quote:

"The observational record of Antarctic mass loss is short and the internal variability to ice sheet is poorly understood. Due to a low level of scientific understanding, there's low confidence in attributing the causes of the observed loss of mass from the Antarctic ice sheet since 1993."

So they just -- their record of observation is short. Their understanding of the natural causes is poorly -- they have a poor understanding of that. And that's just because science is studying these things and different scientists are disagreeing.

And that goes back to my point. Chevron looks to the IPCC because you have all these scientists coming together trying to reach scientific --

THE COURT: When you say "Chevron," I thought you were talking for all the defendants. But are you just -- do all defendants agree with that?

MR. BOUTROUS: I'm just talking for Chevron today.

THE COURT: All right. Okay. I'm going to ask them at some point whether they agree with everything you've said.

MR. BOUTROUS: Okay, Your Honor. I don't think anyone has ever agreed with everything I've said. But maybe it will happen.

THE COURT: Okay.

MR. BOUTROUS: And so that's Antarctica. And maybe this is a good place to pause. The Plaintiffs have taken a different approach today, I think, and citing studies sort of different studies from different folks. And some those go beyond IPCC AR5.

But Chevron -- and we focus on what is the scientific consensus as the best available science pursuant to the Court's request. And then, we have AR6. We will no doubt, you know, look at these issues again, and we'll see what it says.

THE COURT: I got a question for you that relates to this Antarctica part. It may be since you know the IPCC report, a few weeks ago on television I saw a geology show. And it was about volcanos, but it described an under see thing called: "The Ring of Fire."

Doesn't that sound like something from Johnny Cash? But, honestly, I'm not making that up. It's called "The Ring of Fire." And it's a undersea system of volcanic accretions, or something, that's under the Pacific Ocean. And it starts down there at the bottom of South America, runs along the coast all the way up to Alaska, curves over to Japan, then goes down into Indonesia. And the idea is that it is pumping out lava under the ocean which sometimes forms islands and is one possible result.

And it also affects the undersea life and other things. It had nothing to do with this, but I got to wondering: Do these models -- and maybe you may know -- does the IPCC, that seems like heat from inside the Earth that's normally insulated, you know, molten lava way down there, but it's coming out. Does that warm up the ocean and have anything to do with Antarctica melting away? Or has that obviously been debunked by somebody?

MR. BOUTROUS: Your Honor, I'm going to say I don't know. We'll take a look.

THE COURT: The IPCC, any of that.

MR. BOUTROUS: Not that I remember specifically. You know, they talk about different features that can heat the ocean and natural formations and the like.

But we'll go back and take a look. And I'm going to leave behind for you the big Working Group I.

THE COURT: I promise you that is a real scientific term. I did not make that up. It really exists. And I've seen it in other places. Okay.

A note has come from the rear.

MR. BOUTROUS: A note has come, Your Honor. It just came back to me that it's a very recent discovery, and so it was too recent for the IPCC.

THE COURT: No, this Ring of Fire thing has been around since at least 20 years. This is not recent.

MR. BOUTROUS: Well, I'm going to look into this further.

THE COURT: Look into it.

MR. BOUTROUS: I like the name of it and it sounds interesting, so I'm going to look into that further.

So and I think Dr. Griggs had talked about -- and I just to tie it a little bit to what he's talking about -- he was talking about the contribution of Antarctica and the melting, but just to finish up on Antarctica, the IPCC in its latest report says, you know, there are uncertainties about the degree to which human activities are contributing to the ice melt there.

THE COURT: Okay. But, nevertheless, it is melting, isn't it? So how much is -- what is the level of sea? Let's go to that question.

MR. BOUTROUS: I was just going to sea level.

THE COURT: Your view of how much this ocean is rising.

MR. BOUTROUS: I'm going to give the Court the IPCC conclusions that cuts right into this.

THE COURT: All right.

MR. BOUTROUS: So Chapter 13 of the Working Group I has an entire discussion. It's all about sea level change. This figure is from the IPCC, and it simply just depicts the components of sea level. You see the glaciers on the left, ice sheets on the right, ocean properties, which refers to ocean warming which would tie into the Ring -- was it "Reign of Fire"?

THE COURT: Ring, Ring of Fire.

MR. BOUTROUS: Which we're going to check into.

And the ocean, because when the ocean warms it expands which can cause sea level to rise. And then, you have geocentric sea level, which refers to a method for measuring sea level from the center of Earth that I'll touch on more in a minute.

And in looking at the many components of the sea level and the sea level rise the IPCC states, quote:

"The primary contributors to contemporary sea level change are the expansion of the ocean as it warms and the transfer of water currently stored on land to the ocean, particularly from land ice glaciers and ice sheets," close quote.

So we go to the next slide. And this is heading towards your the question you just asked me. This chart reflects global sea level since 1700.

You see that the IPCC says, quote:

"Evidence indicates that the global mean sea level is rising, and it is likely resulting from global climate change, ocean warming includes land ice."

If we go to the next slide --

THE COURT: Wait. Wait. Wait. Stick there.

MR. BOUTROUS: Yes.

THE COURT: It says:

"Corrected for isostatic and tectonic contributions."

What does that mean?

MR. BOUTROUS: Isostatic, Your Honor, refers to the reaction of land. Once the ice melts, it releases pressure, so the land will rise. And so they are correcting for that feature.

So if the glacier starts to melt land has -- the pressure on it releases so it rises, so they are corrected.

Tectonic contributions just refer, I believe, to natural shifting, tectonic shifting. So they have corrected for those features to try to factor them out of the analysis.

THE COURT: Well, all right. But does that mean that the sea level actually has not risen or has risen even more?

Okay. According to this, the sea level is going up. I can see that. But it's corrected for two things. So is the actual sea level going up, as measured, say, at Santa Cruz or at San Francisco?

MR. BOUTROUS: I can't go beyond really what the IPCC has said here with respect to their view, taking those factors out. But the Court's question goes to how do you translate these global assessments to localities. And that's another topic that I'm going to get to, because it's a very good -- what does it actually mean for a particular place? And so maybe I'll just move to -- kind of move to that.

THE COURT: All right. Go ahead.

MR. BOUTROUS: So the Court can see that. So just to kind of finish off the sea level change and the rate, this chart has the sea level rise, the rate in terms of sea level rise over decades.

And the IPCC concludes that, quote:

"Variability is marked by an increasing trend starting in 1910 to 1920, and a downward trend starting around 1950, and then an increasing trend in terms of the rate of sea level around 1980."

So it starts increasing. Then --

THE COURT: Wait. Wait. Wait.

MR. BOUTROUS: Yes.

THE COURT: So this is saying that even as far back as -- that as far back as 1900 the sea level has been going up.

MR. BOUTROUS: And that the rate of increase at least in 1910 to 1920 was increasing. Then, there was a downward trend. And then, starting around 1950 an increasing trend.

But you are right. I think if we go back to one of my earlier slides, that is the sea levels have been rising for thousands of years.

THE COURT: All right. But the rate of change of the increase or rate of the increase, it looks like from 1950 to -- 1940 something to 1960, it went down. But it was still going up. But the rate of change was smaller, but then it started coming back up again. The rate started creeping back up again.

MR. BOUTROUS: Your Honor, you'll see --

THE COURT: Is that about right? Okay.

MR. BOUTROUS: I think that's correct looking at the chart. And if you go to the next slide, it's interesting to compare. And the IPCC does this. So the IPCC concludes that:

"It is likely that the global mean sea level rose between 1920 and 1950 at a rate comparable to that observed between 1993 and 2010," close quote.

So back in that 1920-1950 period the rate was comparable to the rate that the IPCC detects from 1993 to 2010.

THE COURT: So what happened? What was going on in 1920 to 1950 that might have influenced that?

MR. BOUTROUS: Well, there was the warming that was going on then, if we go back. It was, I think, the period when they were having difficulty discerning precisely what the cause of it was. That's, I think, Your Honor, where they say "natural forcings." Probably -- excuse me -- internal variability. I'm not sure that -- well, in fact, I don't think the IPCC does actually explain in terms of causation what was causing that warming compared to more recent times, and then make the connection.

So if we go to the next slide, this is -- I'm going to kind of get local. Talk a little bit about taking these conclusions to globally.

This is, again, right out of the IPCC AR5. And I mentioned geocentric sea level earlier. And here's how the IPCC describes it, quote:

"Since the late 20th century, satellite measurements of the height of the ocean surface relative to the center of the Earth, known as geocentric sea level, show differing rates of geocentric sea level change around the world," close quote.

And just to orient all of us, you have the bar, the colored bar on the right, the sea level. The blues are sea level decreasing, sea level rates decreasing.

And then, you have, as we go up we get into yellow, towards the red. That's the increase. And so with respect to San Francisco and the West Coast of California, the measurements, they have measurements for that.

And if we go to the next slide --

THE COURT: Well, wait.

MR. BOUTROUS: Yes.

THE COURT: If this is accurate, San Francisco has gone down.

MR. BOUTROUS: That's what the IPCC report says using the geocentric sea level change measurement. So you anticipated the very next quote I was going to put up there. That the, quote:

"Those in the Eastern Pacific Ocean, those sea level increases are lower than the global mean value with much of the West Coast of the Americas experiencing a fall in sea surface height over the same period," close quote.

THE COURT: You know, it's funny. It's odd to me. You would think like a pond, the pond is the same height all the way across. Right? But you're saying the ocean can have a higher sea level in Indonesia than it could at, say, Easter Island.

Seems to me like it ought to all be the same. Right?

MR. BOUTROUS: There are a lot of different factors in play. And I mean, I think this just shows using this geocentric sea level measurement -- and, again, talking about the rates of increase here they show the blue. And the light blue would mean that the sea level rate has gone down. And it differs around the globe. So that is kind of what has happened --

THE COURT: That red up there by Greenland is where the Greenland is melting away. And so it's deeper there, that is -- what's going on up there?

MR. BOUTROUS: You can definitely see the differences on this chart in terms of how the IPCC is depicting it.

THE COURT: Okay. You can see it very clearcut over there by Indonesia, New Guinea, Philippines. It's a big difference there. What accounts for that?

Or does the report say why it would be so much higher there?

MR. BOUTROUS: Your Honor, I have to go dig into that particular locale. But it's really -- what I'm sort of about to get to is the complications of, you know, translating the projections and the global rates around to different places.

THE COURT: Okay. Go ahead.

MR. BOUTROUS: Okay. So just to kind of put this in perspective, these are looking to the future, and projecting sea levels. The IPCC has made some projections. And I will just walk the Court through this. Another one from AR5.

And you'll see that on the left we have the scenarios which we've talked about before, the different emission scenarios ranging from the lowest scenario of 2.6, and the highest of 8.5.

And then, if we go -- let's start with 8.5. If we go all the way over to the right to likely range, the IPCC is saying that -- it's saying that the likely range of sea level rise during the period that they are depicting here is -- this goes all the way to 2100.

So I think Dr. Griggs and Plaintiffs has talked about 2100. They say the likely range in sea level rise at the most extreme emission scenario is .45 to .82 meters. And that translates to about 1.5 to 2.7 feet. They say that the lower emissions scenario, the likely range is .26 to .55 meters, or about .9 to 1.8 feet.

So that's what that is depicting, that chart is depicting.

Then they say -- this is the quote at the bottom from the IPCC, quote:

"The basis for higher projections of global mean sea level rise in the 21st century has been considered and it has been concluded that there is currently insufficient evidence to evaluate the probability of specific levels above the assessed likely range."

So they are saying that they -- I'm sure you understand. They are saying they can't predict a higher range above the likely range that is assessed here.

And that really --

THE COURT: Well, okay.

MR. BOUTROUS: Go ahead.

THE COURT: Wait. Wait. Says it's 2046 to 2065.

MR. BOUTROUS: Um-hum.

THE COURT: That's an odd -- why are they trying to -- what is that calculation? What is happening in 2046 that would cause them to select 2046?

MR. BOUTROUS: Your Honor, I'm not sure what the predicate was for picking these two time frames. But, again, I can go back and nail that down.

THE COURT: No. No. No. Well, all right. Let me just make sure I understand.

MR. BOUTROUS: Yes.

THE COURT: In the time period of 2046 to 2065, is this chart saying that at the most favorable, the mean rise will be .24 meters?

MR. BOUTROUS: Yes, Your Honor.

THE COURT: All right. So that's a -- what is that? About 10 inches? What does that turn out to be? I think so, but that's meters or is it -- it's meters.

MR. BOUTROUS: Yes, that's meters.

THE COURT: .24 meters here?

MR. BOUTROUS: Yes.

THE COURT: So that would be a quarter of a meter, which is about nine and a little over nine inches.

MR. BOUTROUS: Right.

THE COURT: So that is saying at the most conservative level, the sea level around the world will go up 9 inches by the time period indicated, 2046 to 2065. Is that what that means?

MR. BOUTROUS: That's how I read it, Your Honor.

THE COURT: And then, the other end it goes up to .3, which would be more like 12 inches.

MR. BOUTROUS: Um-hum.

THE COURT: All right. So okay.

MR. BOUTROUS: Yes.

THE COURT: All right. Okay. Thank you. I think I understand. This is from the IPCC, as well.

MR. BOUTROUS: Yes, correct. And that really ties or brings me to just briefly to address several of what Dr. Griggs was discussing. And now that he's left, I can really -- perfect time to address it.

THE COURT: You can go to town.

MR. BOUTROUS: Yes. But I won't because I'm going to go right to what they say. So he talked about the -- if we go to the next slide, this is a chart from Rising Seas in California, the study that you'll see he's one of the authors.

And he talked about the 10-foot scenario. And he said it could happen. And as I said, the IPCC in that last chart said we can't predict higher ranges than we do on this chart. There's just not evidence.

But even Dr. Griggs' study, if you look at the 2100 line, and this is at the 8.5 scenario. So this is the most extreme emissions scenario.

If you go to 2100, Dr. Griggs' study says there's a .1 percent chance of a 10-foot sea rise.

THE COURT: Over what period? Over what period of time?

MR. BOUTROUS: Up till 2100. So this goes -- this is their projection. It's a 2017 study. So it's projecting forward 2100. So .1 percent.

THE COURT: So between now and the end of this century.

MR. BOUTROUS: Yes.

THE COURT: There's a 1 percent chance.

MR. BOUTROUS: .1 percent.

THE COURT: I think it says 1 percent. Maybe I'm looking -- oh, I see. It's way out there.

MR. BOUTROUS: Way out there, yes.

THE COURT: A .1 percent chance. I can't read the top of that.

MR. BOUTROUS: 10-foot.

THE COURT: 10-foot what?

MR. BOUTROUS: 10-foot rise in the sea level in San

Francisco. And that you'll recall the Plaintiffs do mention that 10-foot number in their complaint. Dr. Griggs mentioned it today.

But even his own study is saying that is, you know -- there's a .1 percent chance. Even if you look at a 3-foot rise they say a .2 or 28 percent chance of a 3-foot rise.

THE COURT: All right. So 2 feet is 70 percent. Right?

MR. BOUTROUS: Let me go to two. Yes.

THE COURT: And 3 feet is 28 percent.

MR. BOUTROUS: Yes.

THE COURT: So somewhere in-between is 50 percent. What would you think that is, two-and-a-half?

.4? So in other words, fifty/fifty chance of something in the range of 2 to 3 feet --

MR. BOUTROUS: Yes, in fact --

THE COURT: -- by 2100. That's still a lot of water, isn't it?

MR. BOUTROUS: Well, really, it's -- if you look back -- and this is the most extreme emissions scenario and it's sort of more in the ballpark, if you look their actual where something is more likely than not to happen, it's in the one to --

THE COURT: How do you know? You said it was the most extreme scenario. How do you know it's the most extreme?

MR. BOUTROUS: It's the most extreme scenario that the IPCC used. You see up in the corner "RCP 8.5"? That's the highest emissions scenario that the IPCC uses.

THE COURT: "RCP" again stands for?

MR. BOUTROUS: Reconcentration of -- testing my memory.

RPC -- probably have it on another note.

And, by the way, Your Honor, I should say we don't necessarily agree with Dr. Griggs' numbers. But I'm just giving you sort of what they reported, which is just as a matter of fact the likelihoods they have used.

THE COURT: All right. It would be interesting to know if it really is the most aggressive scenario. So you're telling me it is, but how do you know that?

MR. BOUTROUS: And when I say that, Your Honor, I'm not saying that it's the most aggressive scenario anyone has come up with.

It's the representative concentration pathways, what "RCP" stands for.

It's the most -- the highest emission scenario that the IPCC used in AR5.

THE COURT: Okay. So -- so the underlying, or the beginning assumption it's the highest emissions projections. But in terms of just the modeling of what would happen is it conservative, medium, aggressive? Do we know?

MR. BOUTROUS: It's aggressive. It's the one that assumes that -- and I'm using laymen's terms -- but that nothing will change in terms of any mitigation or to slow down or alter greenhouse gas emissions.

So, again, I really just wanted to make the simple point that Dr. Griggs mentioned 10 feet. The complaint mentions 10 feet.

.1 percent possibility. And then, back when you go into again, not even forcing their data, but the sea level rises are closer to and slightly higher than the IPCC assessments for through 2100.

So with that, I'd like to just now move a little bit into the coastal flooding questions the Court asked about and just really quickly zip through the sort of the principal findings from the IPCC.

They said that:

"Due to sea level rise projected throughout the 21st century and beyond, coastal systems and low-lying areas will increasingly experience adverse impacts such has submergence, coastal flooding, and coastal erosion, open paren, (very high confidence)," close person, period, close quote.

They also make a finding that predicting local effects and local trends -- well, let me just read it.

This is the point. It goes back to one of your earlier questions that I said I was going to address. They say they make that broad finding that I just read, but then they say:

"While it is likely that extreme sea levels have increased globally since the 1970's comma, mainly as a result of mean sea level rise due in part to anthropogenic warming, comma, local sea level trends are also influenced by factors such as regional variability in ocean and atmospheric circulation, subsidence, isostatic adjustment, coastal erosion, and coastal modification.

As a consequence, the detection of the impact of climate change in observed changes in relative sea level remains challenging."

And I think if I am remembering right Dr. Griggs' slide 12 said something along the following lines:

"Probabilities of specific sea level increases can inform decisions."

And what the IPCC is saying there are all these other factors when you're looking at what is the impact going to be on a local locality.

And in terms of informing decisions I thought I would just end with given the state of science and looking forward, in language really consistent with what I just read, San Francisco said it's to bond 20-year bond investors. This was 2017. That's, quote:

"The City is unable to predict whether sea level rise or other impacts of climate change or flooding from a major storm will occur, when they may occur and if any such events occur, whether they will have a material adverse effect on the business operations or financial condition of the city and the local economy," close quote.

And then Oakland in August, 2017, made a very similar disclosure to its investors. So translating all of this to what is going to happen in a local city is, I think, reflected in the terms of the somewhat unpredictable nature of that by the very recent bond disclosure of two cities.

And with that, I have concluded my part two.

THE COURT: Thank you, Mr. Boutrous.

MR. BOUTROUS: Thank you.

THE COURT: Great. I'd like to see if my court reporter is able to continue on? Let's see if we can finish up and go back to the Plaintiff.

MR. BOUTROUS: Your Honor, just one more. You had asked in your order about two documents and asked the Plaintiffs to produce them.

THE COURT: Yes.

MR. BOUTROUS: I don't know if the Court -- I'm happy to address them. I can very briefly address them because I do have just two minutes.

THE COURT: No, let's do it -- I want to give the Plaintiff an opportunity. If we have time you can address it.

MR. BOUTROUS: Okay.

THE COURT: I want to go back to the Plaintiffs' side first on the tutorial.

MR. BOUTROUS: Thank you.

THE COURT: All right. About half an hour, please.

MR. BERMAN: Thank you, Your Honor.

We are going to -- with respect to the state of the science, I thought you would like to hear from a scientist who has worked on the U.S. Climate Assessment. The U.S. Climate Assessment is the government's state of the art announcement as to climate change.

So rather than refer to the IPCC, as Mr. Boutrous has done, Dr. Wuebbles -- that's W-U-E-B-B-L-E-S, who is one of the coauthors of the report and also has been an author of many of IPCC's studies, is going to present what we think the state of the science is.

And I thought it would be helpful to hand up to the Court the summary of the U.S. Government's special assessment.

THE COURT: Sure. Make sure you show Mr. Boutrous --

MR. BERMAN: Yes, I will.

THE COURT: -- what you're giving me.

Angie, could you hand that up to me? Thank you.

All right. This is called: "U.S. Global Change Research Program entitled Climate Science, Special Report, Executive Summary, Fourth National Climate Assessment, Volume I."

All right. And you are Doctor?

MR. WUEBBLES: I'm Don Wuebbles.

THE COURT: Wuebbles.

MR. WUEBBLES: Wuebbles.

THE COURT: Got it. Go ahead.

MR. WUEBBLES: Yes. Thank you, Your Honor.

It's a pleasure to try to talk about the outcome from that assessment.

Before we get into that, though, I think it's also important to recognize that -- well first of all, I led chapter one of IPCC AR5.

THE COURT: You read or wrote?

MR. WUEBBLES: I wrote.

THE COURT: You wrote.

MR. WUEBBLES: I led, so I led chapter one.

THE COURT: You're the one who wrote it?

MR. WUEBBLES: I wrote a chapter along with colleagues.

THE COURT: All right.

MR. WUEBBLES: We had colleagues on the team. And we had to stop referencing any papers after 2012 in that document.

And I think it's important to recognize that science did not stop. There's a lot we have learned over the last five years. And the National Climate Assessment does reflect that.

So but what you have is the Executive Summary of, is part of a 475-page report that's available on the web through "science2017.globalchange.gov."

And I'm going to talk to that today. That assessment is the most comprehensive assessment of climate science ever done for the American people. It was required by Congress, in general. The Global Change Act of 1990 requires that every so often there be an assessment of the state of the understanding of climate change and what it means to the American people. And this is the fourth such assessment.

And this was the most comprehensive look at the science that we've done in those assessments.

It involved over 50 scientists from throughout the country representing all sectors: Government, academia and industry. and it went through a very extensive review process.

The six different levels of review: A public review, reviewed by the National Academy of Sciences and four different reviews by the U.S. agencies, ending up being finally released through the White House after the final signoff by the U.S. agencies. And we released it in November of 2017.

The second volume will look at the impacts of climate change, and that will be published later this year.

So what does that assessment tell us? This is more like many of the things we've been hearing today. Our climate is changing. It's changing very, very rapidly. It's happening now, but it's changing so fast that it's about ten times more faster than we've seen in any other changes since the end of the last ice age.

So it's very unusual, certainly in human experience.

It's not just the temperature that is changing. We're seeing severe weather becoming more intense in many cases.

We've had a lot of discussion today about sea level rise and certainly sea level is rising. And the evidence strongly indicates it's largely happening because of human activities.

And that the climate will continue to change over the coming decades, no matter what we do. But certainly our choices for the future could make a strong impact on just how large those changes are.

In fact, that's probably the single largest factor, as we look at those scenarios once again that you've already seen several times today.

So we have many different types of indicators of the fact that the climate is changing. These are just some of them. So it's not just temperatures, not just looking at the land air temperature or sea surface temperatures, or even atmospheric temperatures in the middle of the troposphere, but also the fact that the heat content of the oceans is increasing dramatically.

About 90 percent -- over 90 percent of that heat is produced by the increasing amount of greenhouse gases and carbon dioxide and other gases is ending up in the oceans.

And that is increasing the heat content and we have that well measured now.

On top of that, a warmer atmosphere should hold more water vapor. And if you look at the second from the bottom graph of specific humidity, you find specific humidity is being observed increased.

And then, we've already talked a lot already today about how glaciers and land ice are decreasing. Also the Artic sea ice is increasing extensively.

In addition to that, the Northern Hemisphere's snow cover has decreased dramatically.

Going back to the temperature record you have seen several times now, we've seen about a 1.8-degree Fahrenheit increase in temperature from 1901 to 2016.

And if you looked at that temperature record over the last five decades, you'd see that the temperature on a decadal scale has increased dramatically over that time period. And that that's likely to continue to happen over the coming decades.

Now, if we take that temperature record, that observed temperature record, and go back to some of the proxies that analyze what the climate looked like, say, over the last 2000 years, we find that those proxies show the medieval warm period. They show the period that was the period when the Vikings were in Southern Greenland.

They also show the little ice age when it was extremely cold in North America and Europe.

And then, if you look at the current temperatures you see that those current temperatures are well above anytime in those past 2000 years.

So the kind of temperatures we're already seeing are well beyond the past human experience and having a significant impact on us in many different ways.

If we look globally at those changes in temperature we don't have observations in the Artic or the Antarctic region, going all the way back to 1901. They basically started in the Artic region around 1940's.

But -- and so I can't show the change for those. But mostly the area of the globe is increasing dramatically in terms of its climate. The largest charges are happening in the Artic. I'll show you them a little bit more later.

But we've also seen the most significant changes over land masses because the oceans have a very large heat capacity. And so the oceans respond at a much slower rate.

There's two areas on here that are not showing an increase. One is -- the biggest area is the area off the coast of the Greenland in the Atlantic Ocean where all that fresh water we're getting into the Atlantic from Greenland and from melting the sea ice is causing a change in the circulation pattern in the Atlantic Ocean, and actually causing a slight cooling effect in that region.

The other area is actually in the Southeast United States. Before going on to that, though, I wanted to mention that if we look at that period since the end of the last IPCC report, 2014 was then the warmest year on record. 2015 was even warmer. 2016 was warmer yet. And now we have the records for 2017 which ended up being either second or third in that list.

In total, 17 of the last 18 years on record are the warmest years over that entire -- over that entire period since 1881, when we have global representations of the temperature record. So we're in a very unusual time period.

Looking at the United States, most areas of the United States have also seen extensive warming. The one exception is some parts of the Southeast. We don't fully understand why the Southeast is different. There's some suggestion it could be due to some changes in weather circulation patterns.

But on top of that, there was a deforestation in the 19th century in that part of the country and a reforestation in the 20th century that could also be a major contributor to what is occurring there.

But, nonetheless, most of the United States has seen a warming. And the overall temperature change for the United States is 1.8 degrees Fahrenheit since the 1890's.

Looking at precipitation we've seen about a 4 percent increase in precipitation over the United States as a whole. But the changes aren't happening even, nor do we expect them to. In fact, generally globally what is happening is the weather is getting wetter and the dryer is getting dryer.

And so in the United States we're seeing particularly an increase in precipitation in the Midwest and Northeast, while the Southeast and Southwest -- most of the West, actually -- has seen a decrease in overall precipitation.

Changing to the Artic, just to mention this one more time, that it's increasing at twice the rate -- this temperature is increasing at twice the rate of the rest of the world. Kind of the canary in the coalmine, to some extent.

And then, we're seeing much larger changes there, and it's causing issues as a result.

We're seeing very significant decreases in sea ice cover and in glaciers in Alaska, for example, but also major mass losses in the Greenland ice sheet and reduced snow cover.

And, perhaps most importantly, a melting of the permafrost. And that's causing infrastructure damage already in Alaska and other parts of the Artic.

But on top of that, the big fear with those melting permafrosts is that before the end of the century we could see an emission of carbon dioxide and methane that is trapped in that permafrost actually being released back into the atmosphere and causing additional warming.

It's one of those surprise factors that I'll talk about a little later.

So I mentioned that it's not just temperature and precipitation. It's really having many effects on us because of effects on extreme weather and weather and climate events, many different types. And we'll talk about some of these as I go forward. But, you know, they include things like heatwaves, colder waves, wildfires, major storms, et cetera.

One of the ways we know that climate change is already having an effect on the American people -- and actually there are similar analyses being done for the entire world -- is to look at what NOAA has been tracking for the last 37 years -- almost 38 years now -- in terms of looking at what are called the "Billion dollar events."

These are events that cause at least $1 billion in infrastructure damage, for a particular event. And if you go back to the early 1980's you see that we used to have a couple such events, and now we're tending to get well over ten such events. And these do account for economic changes and other factors. And they affect all parts of the country.

So the net effects on the American economy has been now about $1.5 trillion, including 2017.

If you looked at 2016, there were 15 such events. 2017 had 16 such events. And, in fact, was the costliest yet on record beating out the year of Katrina.

If we look at extreme events, and what's happening to these extreme events -- and we discuss this in much more detail in the assessment -- heatwaves, generally, are increasing in the United States, particularly since 1960, globally, since the turn of the century.

In the U.S. we also had some special events happening in the 1930's with the Dust Bowl that caused that to also be a period of high heat in the United States.

But since 1960, we nonetheless have been seeing increase in the number of the heatwaves. These are multi-day events where the temperatures are above normal where you tend to get the most damage.

Cold waves, generally, are decreasing.

More precipitation is coming as larger events. I mentioned that warmer atmosphere holding more water vapor. Well, that leads to extra precipitation. Almost all parts of the country have been seeing an increase in the amount of precipitation when it does happen.

So when you get a rainfall or snowfall you're more likely to get larger events than you had in the past. That means that in some areas you're getting the largest effect of those increases in precipitation. We're seeing more risk of floods, particularly in the Northeast and Midwest. And other areas where it tends to be dry, we're getting less precipitation and dryer spots and warmer temperatures.

We're tending to get more droughts, particularly in the Southwest and Southeast. We're also seeing significant incidents of larger wildfires. More areas being burned as a result of the warming and how that's impacting upon the biosphere.

And the result is that we're seeing significant increases in such wildfires in the West and Alaska. Talk about that a little more in detail in a second.

And, overall, we're seeing an increase in intensity of hurricanes, particularly Atlantic hurricanes. And if we look at the projections for the future very careful analyses are now suggesting through several different approaches that hurricanes are likely to become more intense in the future.

Tornado activity and hail are something we know less about because we just don't have sufficient data. But, nonetheless, we are generally finding that tornadoes are increasing in number of outbreaks. So when you get one tornado, you're more likely to have multiple tornadoes.

And also that hail appears to be becoming more intense. All of these trends are likely to continue over the coming decades.

So if we look at the -- just one way of looking at heat, how many records are being set each year?

We're generally finding that many more heat records are being set than cold records. And that's just one way of looking at that.

If you look at extreme precipitation we're seeing strong trends. The one -- the graph on the left is for the United States, Continental United States as a whole. Looking at the one-in-five-year events and showing a general increase over the last five decades; that in such events the amount of -- the amount of precipitation from such events.

And the right-hand side looks at the 1 percent, top 1 percent of precipitation and showing an increase throughout the entire Continental United States, but particularly in the Midwest and Northeast. A little bit less over the West where we have less overall precipitation in general.

Looking at wildfires this last year we had more than 9.2 million U.S. acres burned, one of the largest years on record.

The U.S. fire season now is about three months longer than it was 40 years ago because of the warmer temperatures that are affecting our climate.

The average fire is much bigger and hotter than before. They are burning as hot as 2000 degrees Fahrenheit compared to 1300 for a small --

THE COURT: Can I ask you a question about the fires?

MR. WUEBBLES: Sure.

THE COURT: I totally agree that the fires have gotten worse and worse. I think it's 1.3 percent of California alone burned up last year just in one year. Now, when that happens, though, doesn't that put a lot of carbon dioxide in the air?

MR. WUEBBLES: It does. You do readmit carbon that had been trapped in the soil and in trees into the air. Yes, it does contribute.

THE COURT: Well, that could be -- is that a tiny factor --

MR. WUEBBLES: In terms of the overall change that's still a small factor because there's also -- you tend to not too long after such an event, you then start having trees growing again, and you start pulling carbon back out.

So the overall factor is small, but you do see fluctuations in the amount of CO2 growth per year.

THE COURT: You know, those trees -- listen. I know how fast those trees grow. They don't grow fast. It takes 40 years to replace a tree.

MR. WUEBBLES: Yes, to replace a tree the same size. Yes, definitely.

THE COURT: So in the meantime you're putting all that carbon dioxide in the air.

MR. WUEBBLES: Yes.

THE COURT: And I'd be interested to know how -- is that a small factor compared to fossil fuel? Wood is not a fossil, so it's not a fossil fuel, but it is a fuel. So I'd be interested to know how the wildfires factor in to the overall CO2 contribution.

MR. WUEBBLES: I think in terms of the over -- I don't have the statistics on that. I think because of the total areas being burned each year it is still relatively small compared to the planet. That is still a rather minor contributor.

THE COURT: I saw a satellite picture. They can see the fires from the satellites.

MR. WUEBBLES: Oh, definitely.

THE COURT: So I don't know how small. I think it's -- okay. I just wondered if somebody could do the math to figure out how much CO2 is coming out of the wildfires.

And by the way, you know you got them in Australia, too. They have them in many places in the world.

MR. WUEBBLES: No, that's true.

THE COURT: In Canada. So all right. I interrupted you. Let's see. I think we got about ten more minutes to go.

MR. WUEBBLES: Uh-ho.

THE COURT: And we got to bring it to a close.

MR. WUEBBLES: Okay. So in the Alaska, even the tundra is experiencing wildfires.

So as we heard today -- and I just want to emphasize this one more time -- that there are many lines of evidence demonstrating that human activities are primarily responsible for the observed climate change.

It is not the sun. The sun has decreased slightly, if anything, over recent decades based on very accurate satellites observations.

It's not natural variability. There are no natural cycles that can explain the long-term record.

THE COURT: In your last ten minutes, you heard what the other side said. Right? Right? You were here.

MR. WUEBBLES: Yes.

THE COURT: So they seem to be agreeing that -- not "seem to be" -- they do agree that humans are putting CO2 into the air. That that does, in fact, cause warming. That does, in fact, cause sea level rise.

Now, there may be a disagreement over which model you use and how fast, how much damage that is going to do and how soon.

What critique would you make of what I just heard from the other side? They seem to be largely agreeing --

MR. WUEBBLES: No, that's exactly right. But that's not what you see overall in the media, and so that's why these points are emphasized.

The evidence does clearly point to the increase in greenhouse gases being primarily responsible for the observed change.

And if we look at the next slide, if we looked at the forcing on the climate, this is the -- climate doesn't just change beyond a small amount due to natural variability in the climate system, without some major forcing externally.

And that, such a change is that, for example, from greenhouse gases. So if you look at the human cause forcings over the last 250 years, relative to what's happened with the sun, sun has changed very, very little, and in terms of its output. In fact, we were looking at the period of the little ice age earlier.

The best analyses we have indicate that the minimum period where we had very little sunspots was, in fact, a small change in the amount of solar radiations.

The big factor there was because of very large volcanic eruptions and the effects that those actually had on the oceans.

So --

THE COURT: So your point there is for the little ice age you're saying the major cause was more than normal amount of volcanic eruptions, which puts stuff in the air which cooled off the air.

MR. WUEBBLES: Yes, that's the best analysis we have.

THE COURT: Okay. Good to know.

MR. WUEBBLES: So human activities really have dominated the changes we've seen since the industrial ages started. And they'll really -- the bottom line here, and that's why IPCC came to the conclusion that the previous speaker showed that extremely likely that human activities, especially emissions of greenhouse gases, are the dominant cause of the observed warming seen in the mid-20th century.

Now, I want to get into looking -- you know, all the analyses of the past is really based on observations. Now, we look at the future we have to use numerical models of the Earth system, as others have talked about.

You've heard of these four different scenarios we tend to use to look at that. Those are scenarios that try to look at the business-as-usual case, what we're already doing. Current emissions are higher, at or higher than any of these cases, but certainly most similarly to the RCP 8.5 scenario.

The other scenarios are basically choices we can make, whether they are due to policy or not policy, is that humans decide for one reason or another, for example to move to alternative fuels and other ways of dealing with transportation or energy.

And that's why we looked at four different scenarios.

THE COURT: Well, what are those fuels? What are the alternative fuels you just mentioned?

MR. WUEBBLES: So using solar or wind power, for example.

THE COURT: What other are there?

MR. WUEBBLES: There are certainly a number of others.

THE COURT: Like what?

MR. WUEBBLES: They are starting to extract power from ocean waves. You can use thermal radiation or thermal --

THE COURT: Geothermal.

MR. WUEBBLES: Geothermal, yes.

THE COURT: Okay.

MR. WUEBBLES: Or nuclear.

THE COURT: If we had, you know, back in the '50's we had nuclear power.

MR. WUEBBLES: Right.

THE COURT: So if we had stuck with nuclear power -- I'm just being a devil for a minute. If we had stuck with nuclear power, we would not have needed to use so much fossil fuels. Right? Because we would have had nuclear power.

MR. WUEBBLES: If we had recognized in 1990 all the science we recognized and had started to do something, yes, we would have probably used largely nuclear as the primary --

THE COURT: You think nuclear is safe?

MR. WUEBBLES: We have -- in my state of Illinois, we have seven or eight -- I don't remember how many it is exactly -- nuclear plants. And they have been fine. Nuclear can be safe. You know, obviously there are things to be concerned about that.

I spent 20 years at Lawrence Livermore National Laboratory, which is, of course, a nuclear --

THE COURT: I'm sorry. Which lab?

MR. WUEBBLES: Lawrence Livermore.

THE COURT: Oh, Lawrence Livermore.

MR. WUEBBLES: Thirty miles from here, yes.

THE COURT: Well, but a nuclear would not put out any CO2. Right?

MR. WUEBBLES: That is correct.

THE COURT: And that would be -- we might get some radiation as we drive by, but we don't get any CO2.

MR. WUEBBLES: Right.

THE COURT: So that would have been -- in retrospect, maybe we should have taken a harder look at nuclear to reduce some of this CO_2.

MR. WUEBBLES: As you already heard --

THE COURT: Just a thought. But let's go to the other things. Solar. Okay. There's no doubt that solar is good where you can use it.

But do you really think that could have ever really been a substitute for supplying the kind of power that America has used up in the last 30 years?

MR. WUEBBLES: I think it could be -- this is all getting beyond my scientific expertise, but --

THE COURT: Yes, okay.

MR. WUEBBLES: -- I think solar could certainly be a significant factor of our energy future. I don't think there is any one silver bullet.

It's a whole combination of things that are likely going to be the way we look at energy in the future.

THE COURT: Okay. I need to ask you -- I'll give you five more minutes, and then we got to bring it to a close.

MR. WUEBBLES: So if you go to the right-hand side, the left-hand side was looking at emissions. The right-hand side looks at the change in temperature for those different scenarios or three other of the four scenarios.

It's really the difference in the emissions that make the biggest effect. So our choices for the future in the way of emissions is really is what matters. So if we want to -- it's not the uncertainty of the models that matter as much there.

There are uncertainties in the models. We would acknowledge that, and we can discuss more. But I don't have time for it. But, nonetheless, we're talking about a very significant impact.

If we continue to follow that highest pathway, that business-as-usual pathway, we're talking about changes of eight, nine, ten degrees globally Fahrenheit by the end of this century.

And much tending to be even more so on land masses. So if we look at -- this is from IPCC, actually -- look over the next few decades we get about a 1 degree further change.

Doesn't seem to matter which scenario you followed, because emissions we've already made are going to cause that 1 degree.

Even that's a very significant effect on us, because we've already seen a significant effect from the 1 degree we already have.

But by the end of the century we can separate out these different scenarios and really see it really matters in terms of how big an effect on Earth climate we get depends on which of those pathways we follow.

Now, we can also talk more about extremes. I'm going to kind of skip over that in terms of like the number of days above 90 degrees, numbers of days below 32 degrees, and get a little bit of looking at the oceans.

Now, we've already seen 7 to 8 inches since 1900 of sea level rise. Dr. Griggs showed you that the most recent rate of increase happening really since the end of the last IPCC report is that rate of increase is higher than any time we have seen over the last 2800 years as of result that came out of a NOAA report, but appears to hold well.

We're also seeing acidification of the oceans, because about 25 percent of that CO2 ends up in the oceans and converts it to carbonic acid and contributes to the acidification of the ocean. And we're seeing a change in ocean circulation, as I mentioned earlier.

THE COURT: Wait. I want to go back to the acidification thing.

MR. WUEBBLES: Yes.

THE COURT: You know, we've had a -- I've seen programs on how the coral reefs are dying off. Is that what that is a picture of there? I can't tell.

MR. WUEBBLES: Looks like a reef.

THE COURT: But are you suggesting that the reason the coral reefs are dying is because there's more CO2 being absorbed into the ocean?

MR. WUEBBLES: That's one of the contributors. The warming ocean is also a very strong contributor. The fact that the oceans themselves are warming is affecting it.

And also in certain areas, the reefs are also being affected by global pollution. But, overall, the oceans, in general, are being affected by both of those other factors.

THE COURT: All right.

MR. WUEBBLES: So I'm going to skip over the nuisance flooding, which you've already heard more about.

If you look at the top graph here it shows that greatly increasing rate of sea level rise compared to the past.

From our assessment we came to the conclusion that there's been the projections for the future should be a one-to-four plus increase over this century in sea level rise. But we could not say for sure. It could be as high as 8 feet.

And that eight feet reflects this uncertainty about what is happening on western ice sheet. And that the very recent work since IPCC 2013 has really demonstrated that area is much more vulnerable than we thought before m.

And so that -- so these -- this risk level of something that could be much higher is really resulting from new knowledge that has really changed the picture.

Now, I think one last thing is that the previous speaker talked about sea level rise on the Pacific Coast and that there was this period, which is actually 1993 to 2012, that showed a slight decrease over that time period.

If you looked at the long-term time change, which Dr.

Griggs did show, then you see that overall there's been a trend, and of increasing sea level rise over that, and he came up to about, I think, 7.7 inches over the last century.

If you look at the time period since 2012, you actually go back to seeing an increase in this region. So that is a little different than the picture he was trying to paint in his presentation. Again, the science does not stop at 2012.

THE COURT: If you had no ice whatever, no ice sheets, no, you know, Greenland melted and Antarctica melted, how -- so what would be the maximum possible water level on the Earth?

MR. WUEBBLES: If everything melted? So Dr. Griggs showed you that there was -- in Antarctica there was an equivalent to 190 feet of sea level to, in Greenland, an extra 24 feet and about an extra one-and-a-half feet in all the other glaciers.

THE COURT: Give me those three numbers again.

MR. WUEBBLES: 190 feet from Antarctica, 24 feet from Greenland, and about one-and-a-half feet from other glaciers.

THE COURT: If we add all of those, that would be over 200 feet. Right?

MR. WUEBBLES: Yes. My house in the Midwest could be coastal property.

THE COURT: That could be not quite to the top of Mount Diablo.

MR. WUEBBLES: Oh, yes.

THE COURT: That's 3,000 feet, but most of it would be submerged.

I guess San Francisco would become --

MR. WUEBBLES: We don't expect that to happen, so --

THE COURT: -- Atlantis. Right?

But you don't expect that?

MR. WUEBBLES: We don't expect that to happen in the next few centuries, by any means. It would probably take a number of centuries before that could possibly happen.

One of our concerns, one of the things I wasn't able to get to here was the question of potential surprises.

I've already mentioned the permafrost melting, but you know how much the glaciers do change, how much sea level rise does change could have a --

THE COURT: Give us an example. Give us an example of a theoretical or plausible surprise out of the blue.

MR. WUEBBLES: Besides the permafrost melting?

THE COURT: Yes. Yes, that's a good example, but give us another one.

MR. WUEBBLES: So another one would be the melting of Artic sea ice. We're already having questions of whether the large deviations we're seeing in the jetstream across, particularly affecting various parts of North America, is related to the decrease in sea ice. And whether that in the future would have an even larger effect on our weather patterns.

So that's another aspect. The hydrates, the methane hydrate, the coastal areas of most of the oceans have a lot of methane trapped belowground in the ocean. If that methane gets released, it's going to add to the further warming. We don't think it's going to happen.

THE COURT: Why is methane -- what causes that methane that's underground?

MR. WUEBBLES: It was due to bios, biospheric production.

THE COURT: What kind?

MR. WUEBBLES: Biospheric production.

THE COURT: Oh, biosphere. Okay.

MR. WUEBBLES: Yes. So the changes in El Niño events. You know, if we were to have a lot more El Niño events that would add to the overall warming.

There's a lot of other aspects that are surprises, things we don't really expect but they are things we just don't know about.

THE COURT: When the amount of CO_2 goes up, do the plants get more active and flourish more and take more of the CO_2 out of the air?

MR. WUEBBLES: Yes, I saw that in one of the graphs earlier today, yes. It does happen. I'm a son of a farmer so one of the things we've been concerned about, well, could the increase in CO_2 really help farming for the future?

But ends up it doesn't help seed production that much. So farming is more like agricultural production, crop production is likely to be affected more by the temperature increases than by that factor.

THE COURT: Is there any type of plant like a forest or a rain forest that would benefit from more CO_2 in the air?

MR. WUEBBLES: I think they all benefit to some degree, but you have to put that alongside what changes are happening in the rest of the climate system in terms of the change in temperature and changes in precipitation patterns.

And when you do that, then it's hard to -- it's much more difficult to find benefits in any part of that system.

THE COURT: I wish we had all day, but I got to bring it to a close. So thank you very much.

MR. WUEBBLES: You're welcome.

THE COURT: All right. So I got a couple of follow-up things here. Take your time there, by the way.

You can -- I want to give an order to all the other defendants that if you agree (sic) with anything that Mr. Boutrous said you have one week from today to file a statement explaining each and every statement that you disagree with. Otherwise, I'm going to deem it that you agree.

Any questions on that?

You want two weeks? I'll give it to you. But you can't get away with sitting there in silence, and then later saying:

"Oh, he wasn't speaking for us."

I'll give you two weeks from today at noon.

All right. So that's number one.

Number two. What was number two?

Oh, yes. Are you going to take an interlocutory appeal on the jurisdictional issue?

MR. BERMAN: We are not, Your Honor.

THE COURT: You're not.

MR. BERMAN: We're not.

THE COURT: All right. Then, are you in the other case going to take any kind -- I don't think you have a 1292 B, but are you going to try to make some appeal?

MR. BOUTROUS: We are, Your Honor. We are going to appeal that order, Your Honor.

THE COURT: All right. Now, you wanted to -- I'll give you -- I don't have much more time, but I'll give you two minutes if you wanted to say something about the documents. And I did read the documents carefully.

So I am up to speed on what those two documents said. But I want to give you a chance to make your point on it.

MR. BOUTROUS: I'll be really brief, Your Honor. The timeline that I walked through paragraph 67, for example, the Oakland complaint, when I read it it read to me like they were talking about a document that was secret inside knowledge by this organization they were pointing to.

Well, it turned out it was a summary of the IPCC report from 1995. It was -- those were quotes from the Power Point deck. So I found it to be a bit misleading, very misleading.

And, secondly, that report as I mentioned today talked about the uncertainties and the limits on knowledge.

The next paragraph that the Court asked about the document was a public relations document that talked about making sure the public had more information; that there were uncertainties.

So I thought that the -- I was glad the Court had been produced those documents. We hadn't seen them.

THE COURT: How could you have not seen them? They were from maybe not Chevron files, but from the files of those organizations that Chevron has something to do with.

MR. BOUTROUS: One person attended a meeting or participated in something. We just had not seen those documents. So it was helpful that the Court had them because I think they tell a different story than the Plaintiffs do.

THE COURT: Well, if there's another document in there, too, that you think should be for assessing the complaint I'll make the other side do that.

I found it useful, and I think Mr. Boutrous is correct. I read that paragraph 67 the same way; that there was a conspiratorial document within the defendants about how they knew good and well that global warming was right around the corner.

And I said:

"Okay. That's going to be a big thing. I want to see it."

Well, it turned out it wasn't quite that. What it was was a slide show that somebody had gone to the IPCC and was reporting on what the IPCC had reported, and that was it. Nothing more.

So they were on notice of what in IPCC said from that document, but it's hard to say that they were secretly aware.

By that point they knew. Everybody knew everything in the IPCC. So I don't know. I think Mr. Boutrous makes a fair point.

If you want to respond, I'll let you respond. But I don't know if that had as much to do with today, but if he wanted to respond okay.

Anything you want to say?

MR. BERMAN: No.

MR. BOUTROUS: Thank you very much, Your Honor.

THE COURT: All right. So I want to thank all members of the public. I wore my science tie today. This is something I got with my son at the Lawrence, some lab over in Berkeley. It's a solar system. Earth is on here, Mars. So I hope somebody took notice of it.

All right, my friends. Thank you very much.

We're in adjournment.

MR. BOUTROUS: Thank you.

THE COURT: Oh, please remember all those things you promised me you would get me you have a few days to do it, but I would like color copies, please.

All right. Thank you.

MR. BOUTROUS: Thank you, Your Honor.

(Thereupon, this hearing was concluded.)

Stenography certification

"I certify that the foregoing is a correct transcript from the record of proceedings in the above-entitled matter."
March 25, 2018
/s/Katherine Wyatt
____