Center for American Progress

SPECIAL PRESENTATION

"THE SCIENCE OF CLIMATE CHANGE"

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**12:00 PM – 1:30 PM
WEDNESDAY, FEBRUARY 3, 2010**

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MR. JOSEPH ROMM: So let me start here. I will only just introduce myself. I'm Dr. Joseph Romm. I run ClimateProgress.org which is the center's climate blog that covers climate science and climate solutions and climate politics. I have a Ph.D. in physics from MIT and studied physical oceanography of the Greenland Sea at the Scripps Institution of Oceanography with Dr. Walter Munk.

And let me just run through a few slides. Is that right? Yes. I can't go back. Sorry. Let's go back. Sorry about that. Sorry. There we go. There we go. Fine.

The science of climate change – and Dr. MacCracken and Dr. Field will elaborate on this – we're raising carbon dioxide levels, levels of greenhouse gases. They trap heat and so our planet is our accumulating heat. And scientists have known and predicted for decades that if we keep doing this, it's going to warm up the planet.

In fact, back in 1979, an expert National Research Council panel estimated that if you doubled global CO_2 concentrations from pre-industrial levels, you would warm about three degrees centigrade. And the preface said if you wait, a wait and see policy may mean waiting until it's too late. And so far, for 30 years, we have waited and now we're seeing it.

We're going to talk a lot today about the Intergovernmental Panel on Climate Change, which was set up by the nations of the world to review the science, the scientific literature, and report on it every several years. And it has gotten a lot of attention lately.

I think the key point and I just read a statement here from the oldest scientific society in the world, the U.K. Royal Society together with the United Kingdom Meteorological Office which is actually part of their Defense Ministry, that the 2007 IPCC assessment, the most comprehensive and respected analysis of climate change today, states clearly that without substantial global reductions of greenhouse gas emissions, we can likely expect the world of increasing droughts, floods and species loss, of rising seas and displaced human populations.

However, even since the 2007 IPCC assessment, the evidence for dangerous long-term and potentially irreversible climate change has strengthened. So that will be kind of a dual focus today: what does the IPCC tell us and what have we learned since the IPCC.

I'm just going to put up – discuss very briefly three scientific studies since the IPCC in the scientific literature last year. This is actually a 2009 study of ocean data monitored around the world down to two kilometers, 2,000 meters, a little over a mile, and published in the *Journal of Geophysical Research*, because you hear a lot of talk about is it still warm? Is the planet still warming up?

Most of the heat, over 90 percent of the heat trapped by greenhouse gases was expected to go into the oceans. And when you look in the oceans, the oceans are heating up and kind of steadily. You don't see the kind of fluctuations in the amount of ocean heat storage over the last five or six years that you see in the temperature record. You basically see a relatively steady accumulation of heat in the ocean.

So just one of many pieces of evidence that, yes, as predicted we are trapping heat and the planet is heating up.

This was a study that came out in the fall in *Science*. It was a study of Arctic lake sediments, tree rings and glacial ice by the National Center for Atmospheric Research. This is a figure of temperature – the temperature anomaly over the last 2,000 years, and indeed, one of the conclusions of the study was if it weren't for human emissions, we would probably be entering a long, slow period of cooling, possibly heading even to an ice age.

But human emissions have totally overridden the natural cycles of Ice Ages and interglacial warming. And we are obviously on track to greatly warm the Arctic and it is expected that the Arctic would warm up more than the rest of the planet because of various feedbacks including the fact that when you replace ice with open water, you're replacing something that's very reflective of sunlight with something that absorbs sunlight so you get accelerated warming which leads to more ice melting.

And let me just say, 30 years ago, they said if we doubled atmospheric concentration to carbon dioxide we might warm three degrees centigrade on our current emissions path. If we just keep doing what we're doing, we are headed to go well beyond the doubling of CO_2 concentrations.

And MIT published in the *Journal of Climate* their integrated global model which projected that the median surface warming by the 2090s would be five degrees centigrade and that's just compared to the 1990 baseline, almost 10 degrees Fahrenheit of planetary warming. And the median warming in the Arctic in their scenario is 20 degrees Fahrenheit. We're talking about a completely different planet. And again, this is not the worst case scenario. It's not the best case scenario. It's just what they modeled if we keep doing what we're doing which is to say increase use of fossil fuel emissions.

So let me with that introduce two speakers today. Dr. Christopher Field is director of the Department of Global Ecology at the Carnegie Institution of Washington and professor of biology and environmental earth system science at Stanford University. He was a coordinating lead author for the 2007 IPCC "Fourth Assessment" report. And just in September 2008, he was elected co-chair working Group II of the IPCC and will lead the next assessment, the Fifth Assessment, on climate change "Impacts, Adaptation and Vulnerability."

And immediately to my right is Dr. Michael MacCracken, chief scientist for climate change programs at the Climate Institute. From 1993 to 2002, Dr. MacCracken served as senior global change scientist to the Interagency Office of the U.S. Global Change Research Program, also serving as its first executive director from 1993 to 1997.

From 1997 to 2001, Dr. MacCracken served as executive director of the USGCRP's National Assessment Coordinating Office and during that period, he coordinated the official U.S. government reviews of several of the assessment reports prepared by the IPCC and he was a co-author, a contributing author for various chapters in the IPCC assessment reports. So let's turn it over to Dr. MacCracken.

MR. MICHAEL MACCRACKEN: Okay. Thank you, Joe. Yes, right there. Okay. Okay. Well, I'm going to try and go back over some of the fundamental science on which this rests because I think it's very important to understand how sound the fundamental science is, recognize that this problem goes back quite a ways.

The first suggestion scientifically about human activities affecting the climate was back in 1896 by Svante Arrhenius. There were sort of two questions about his work, one about how fast CO_2 would be taken up by the ocean and one about how CO_2 in the atmosphere, if it wasn't absorbing all the radiation it could and one had to work to understand that.

It took until mid-20th century to understand that. And so there was then a report from the president's Science Advisory Council to the president about atmospheric carbon dioxide by some of these prominent scientists in 1965. So that's the first report that went officially from the scientific community to the president and the Congress saying it's time to do something about this issue, to be thinking about it. And they actually had the science about right on those things compared to today. It hasn't changed much.

So over this time with research back before that and since then, there are really only a few things you need to understand and a lot of the rest is sort of details that are important for understanding impacts but don't change the fundamental issues.

So the first point is emissions from human activities are changing atmospheric composition. It's well established. And I'll show some of that. We're enhancing the natural greenhouse effect, the warming influence that occurs from the gases in the atmosphere. We're changing – there's already changes in the climate that are evident because we've been doing this for a couple of hundred years. We're still adding emissions to the atmosphere so we're going to change it in the future and we're going to have future warming. Climate affects society so we'll have environmental and societal effects. And six, it's going to take a major cut in emissions to stop this from happening.

So I'm going to cover mostly the first three points, say a little bit about the sixth. Chris is going to cover points four and five.

So the first one is really that the composition is changing and there were measurements that started out in Hawaii in the mid-1950s and basically it showed two things: one, it showed that the average over the seasons is going up and that's sort of accelerating and that's the human part.

And this oscillation back and forth is the seasonal breathing of the northern hemisphere, that is from spring into summer, the biosphere grows, pulls carbon out of the atmosphere and then in fall and winter there's sort of – it's sort of released and you get this breathing of the biosphere that you see on satellites.

We believe the Mauna Loa Observatory represents a northern hemisphere's average concentration so if you multiply by that volume, by this amount, you get a seasonal range of about seven or eight billion tons of carbon per year that are taken up by the biosphere. So when you see that greening, that's what it is.

Well, that's about what U.S. fossil fuel emissions are so that's a very important issue. That gives you a sense of what we're doing. It's not going up by that much each year because some of the carbon goes to the biosphere, some goes into the ocean and it spreads to the southern hemisphere but the fact that the rate of increase is going up is directly a result of the fact that emissions are going up. Oops, I went the wrong way.

If you go to get a longer record from when we were taking real observations, you go to ice cores to look into the bubbles and what you see is that not only is the CO_2 concentration going up – this covers the last 1,000 years; we now can go back further and we can talk about that in the discussion – but carbon dioxide, methane, nitrous oxide, are all going up. These increases started with the industrial revolution. The figure bar on the right shows for 10,000 years and you can see again it's a very unusual change. It's not some sort of natural variation.

On the greenhouse effect, solar radiation comes in. About 30 percent is reflected, about 20 percent is absorbed in the atmosphere. About half of it gets through to the surface. Anytime you warm a surface, it starts radiating heat away so the surface is radiating heat up.

It turns out that heat gets largely absorbed in the atmosphere by the molecules in the atmosphere that have more than three atoms, so not the oxygen and the nitrogen but all of the other things – CO_2, water vapor, methane, a whole host of things. And as they absorb, they radiate back. They radiate. If something goes up, something goes down and some stuff comes down. These arrows are proportional in size to the amount of energy and what you see is that it's back radiation to the surface from infrared energy is about twice as large as the solar energy that is actually reaching the surface. And you sort of experience that on cloudy nights when it doesn't cool off a lot compared to clear nights.

There's a lot of reasons we know that changing the concentration can affect the planetary temperature. We can look at the geological history of the earth. We have some reconstructions of what is changing and we know sort of what's happening. You can look at Venus and Mars and the earth and compare that. You can do laboratory experiments. You can do climate model simulations. There's a lot of reasons that it's just sort of pure physics about what's happening. I mean, these indicate that as sort of Joe was commenting, if you double the CO_2 concentration, you'll get a warming equivalent at equilibrium of about three degrees. There's some uncertainty but a reasonably light amount.

So what have we been doing? Well, we've been changing atmospheric composition. And so we've been causing a warming influence from carbon dioxide, methane, halocarbons and a number of other things. The sulfate aerosols we've been putting up exerted a cooling influence. The net effect of all of them is this warming influence. The CO_2 effect increased by sort of 20 percent between '95 and 2005. It's going up rapidly.

The sulfate aerosols have this cooling influence which is important. They're offsetting some of the warming influence and that's nice but there's a provision about it I'll talk about. And so the net effect turns out to be about the same as the CO_2 influence which has led to a lot of discussion that CO_2 is the issue and they don't focus on the other things and I'll come back to that in a moment.

So if you look at this again, the problem in sort of controlling things is going to be that the sulfate aerosols always stay in the atmosphere and so if we even cut emissions to zero, suddenly we have a much higher concentration. We don't have that offset occurring and you'd get up to, if you just consider the greenhouse gases the equivalent of having a CO_2 concentration right now of 450 per million which is sort of pretty high level compared to along the way.

So I've done some interesting calculations which is to say, okay, what is the legacy effect? Let's set all the emissions to zero in about the year 2000, what lasts? Well, the reddish curve is the methane – it's sort of slowly – pretty quickly disappears, some of the ozone disappears and what you're left with is CO_2 carrying on and it really goes out for many centuries.

And so what's contributing in the future? What about 21st century emissions? Well, the red is what the CO_2 is contributing to the warming influence as we look ahead. The green is sort of the methane. The orange is the ozone and then there's some things from halocarbons and other things and also there's some black carbon that is on this particular way it's done.

But what you can see is from the 21st century, the warming influence from CO_2 is about equal to the sum of the warming influence of the non-CO_2 gases. So if we just address CO_2, that's only about half the problem. CO_2 effect carries out for centuries so you'll have to do that but you also have to do this other part of the problem.

So the third point I want to cover is just what's been happening to the temperature. What we do is not try and calculate the average temperature around the earth but the difference, the change in temperature at each location. This gives an indication for 2009 and you see that most of the continent – most of the world is warmer than it was in the last three decades of the 20th century. There's some places each year that it's not quite as warm and it cools and you've got some variations and things but overall it's warming.

If you take that and aggregate it up by average, the blue dots are for each year. What's happening? And you get some noise variation around things, some due to solar, some due to other things perhaps.

But what you see if you take decadal averages is that it was cool in the late 19th century or early 20th century probably due to volcanoes and a little bit of solar radiation and stuff and maybe a lot of sulphur coming out of fuels but as you look what's been happening in the latter decades of the 20th century, you see a rather steady warming. If you start in a particular year, you can get a curb to sort of go anyway but if you look at the averages, it's steadily warming.

So we want to understand if that's human activities. There have been a bunch of model simulations to do that. The black curve is observations. The blue is if you run the models with just natural forcing, namely solar and volcano, then what you see is it sort of matches in the early part of the record but it doesn't match at all well in the latter part of the 20th century. If you add any effects of human influences, you get the pink curve which again matches early on and now matches later in the century due to human activities.

So this was done globally. It's more recently been done in this last assessment in regions, various continents and the ocean regions around the world. It's interesting. The only place that you get a band from the models because of the chaos of the system, the sort of year to year variability, so the question is if the black line is in the pink line, it does pretty well. The only place it really is out of sync is over the ocean during World War II and there's some real questions about measurements and how they were taken during that period and adjustments are – they're getting talked about some – (inaudible).

So the IPCC over time in doing this has in 1995 said, it just suggested discernable human influence but we've done this sort of way of getting at the causes, what's causing what and how it all matches, basically, the fingerprints of the change. And so by the last, the fourth assessment, they're basically saying the warming is unequivocal and most of the observed increase is very likely due to human activities.

There's extensive additional evidence – if you don't like the temperature record, there's extensive additional evidence that confirms that climate change is occurring. You can see it in the average ground temperatures going up, ocean temperatures are going up which – (inaudible) – in terms of heat. Sea ice cover of the Artic is decreasing. Mountain glaciers and permafrost are thawing and melting. Sea level is rising because of more water going in the oceans because warmer water expands. And the last point is really interesting that a lot of plant and animal species are moving.

So let me just finally say a few things about the world of ice. I mean, Artic sea ice is retreating. It's important to figure out why. It's partly due to greenhouse gases. It's probably also partly from cleaning up SO_2 emissions that create a sulfate haze over the region. But we're seeing a very steady decrease. And it isn't just the area. It's the quality of the ice that's getting worse.

One of the questions has been what's happening to Greenland and Antarctica. Some of the survey information has been indicating that the volume is sort of staying the same. If you look at the surface, it isn't changing so much but if you fly over in a satellite that measures the amount of mass by looking at gravitational pull, both Greenland and Antarctica are losing mass because of the way the ice moves.

IPPC in its "Fourth Assessment" wasn't really able to estimate this term and there's been a lot of discussion about this term since that time. That's just that both are losing mass.

So I want to – I mean, as you lose mass from these areas, these ice sheets, you add to the sea level. The rate of sea level rise seems to be accelerating from the 20th century to the 21st. And there's a lot of potential sea level rise held up in these glaciers. So Greenland, for example, has about 20 feet of potential sea level rise, west Antarctica, about the same; east Antarctica more but it's pretty cold.

So you're really worried about what's going to happen to sea level. Most of this past one has been due to melting mountain glaciers and thermal expansion so this addition is going to be the big turn.

Greenland's particularly worrisome because it used to be thought it's a big ice mass up on an island of land or on mountains. And so you had to have hot air get to it to try and cause it to melt.

But what we've discovered is most of the interior Greenland's pushed down below sea level and there's some fiords and the one on the left side of the figure at the middle, sort of the Jacobshaven is where ice is streaming fast. And so you get this potential for sea level rise.

And so IPCC's assessments are sort of these blue bars but if you start getting as much sea level rise as is being thought about, and Bob Bindschadler from NASA talked about it as being sort of another meter of three feet or so over the century, you get a much greater amount of potential sea level rise. So that's the real worry. So as I said, I've sort of tried to cover quickly the first three points. Now, Chris is going to go on and talk about the other ones here.

MR. CHRISTOPHER FIELD: Thank you. You want to wait for questions until the end?

MR. ROMM: Yes. We'll take – yes. And what we're going to do as they say is after Dr. Field finishes, then I'm going to ask them a few questions focusing on the IPCC and then we'll open up to questions from the audience.

MR. FIELD: Okay. Thanks, Joe. And thank you, Mike. I'd like to just kind of reset and revisit a couple of the issues that Mike already talked about, why the climate's changing but I want to put it in a slightly more human terms, why in terms of the way society's work is climate changing.

And then what I'd like to do is give a picture of what we understand about the way those changes are going to impact opportunities for people and future lifestyles and put those in the framework of the way the IPCC does its assessments. Mike already showed you this figure.

This is the historical trend in the atmospheric concentration of carbon dioxide. And he also made a critically important point which is that for more than 100 years we've understood the basic physics of the way carbon dioxide in the atmosphere traps heat and causes the planet to warm. The brilliant Swedish chemist Svante Arrhenius worked it out in detail and essentially the physics that are in Arrhenius' paper haven't been challenged since then. The way that CO_2 influences climate is known to the same level of confidences, for example, how an electric motor works, how a transistor works. There's no scientific uncertainty.

There is however a lot of scientific uncertainty about the amount of climate change we expect in the future because there are two important regulators of the system that aren't included in this fundamental relationship between CO_2 and temperature.

The first is that the climate system is a very complicated and multidimensional group of processes that have feedback that can either amplify or suppress the basic warming that's driven by the CO_2 concentration.

The second is that the primary driver of this increase in CO_2 concentration is things that people do and it's very, very difficult to predict what kinds of human actions will occur in the future.

Mike made some important points about the relative contributions of carbon dioxide and other heat trapping gases to climate change but it's important to recognize that there's a very good reason that the focus has been on carbon dioxide in all of the negotiations to date and in things like the in the U.S.

The reason for that is that historically, we haven't figured out a way to make people rich without also associating high carbon emissions with their lifestyles. This is a figure over about two orders of magnitude of per capita carbon emissions on the vertical axis and per capita economic activity across the horizontal axis. And what you can see is that more or less independent of time, more or less independent of what part of the world you're in, there is a linear relationship in this log-log, plot between carbon emissions and economic activity.

The big issue in climate change for the future isn't how we deal with the current bucket of emissions. It's how we move from an environment where the world is regulated by this relationship to one where we can break the relationship between carbon emissions and wealth and enable people to aspire to their legitimate goals for economic advancement without coupling that with carbon emissions.

We need to move to a future where instead of this relationship that moves from lower left to upper right we start pushing the relationship downwards so that there's the opportunity for more economic activity with lower carbon emissions.

The consequence of the carbon emissions, as Mike says, has been warming and there's been a lot of debate about whether or not there has been a change in the trajectory of warming over the last decade or so. It's very difficult to ascertain trends in a climate record over only a few years because in the short term climate patterns are dominated by the intrinsic variability of the climate system.

And the fact of the matter is that there were some very hot years associated with the 1997, '98 El Nino, 2005 was extremely hot. And this is the global temperature average record from the NASA guess. This is a record that's independent of the UEA record that's been criticized in the CRU e-mail issue. And it shows the 2009 numbers just really as tied for the second warmest year on the record.

But it also shows the high importance of inter-annual variability. And as Mike said, you could start at any point in this record and go forward or backward two or three years and say that it's very hard to find a trend. In fact, if you move your hands along the figure and say, would I have detected a trend in any single decade, it's essentially impossible. Climate is the long-term outcome of a series of processes that are acting over a time scale where the internal variability in the system becomes less important.

But the big controller on what happens with the future of climate is what kind of lifestyle people pick. You know, if we pick on this plot of CO_2 emissions versus time to pursue the kind of trajectory we've been on in the past, a lifestyle that's energy intensive with the energy coming from fossil fuels, we can expect to have rapidly growing emissions so that by the end of the century they could be many times what the current emissions are.

If instead the world decides to move on to a trajectory where the emphasis is on obtaining energy from advanced technologies that are not carbon emitting, we could be on a trajectory that's much more like the green one where it peaks in as early as 2050 and then turns down or if the world decides that globalization, industrialization isn't the way to go and that there's more emphasis on diversified approaches, local solutions kind of green lifestyles, we can see something like the blue line.

It's important to remember that when the IPCC put these scenarios together back in 2000, they characterized them as possible futures that they didn't associate any probabilities with and they kind of explored the climate consequences.

The farther you move into the future, the more which of these pathways you're on controls the outcome. And people need to know that business as usual isn't some place in the middle of this set of trajectories. At least since 2000 actual emissions have been running at or above the highest of the emission scenarios that the IPCC considered in this special report on emission scenarios.

Another important point to know is that in the 2007 report, the highest emission scenario that was analyzed in detail wasn't the red one that's shown here. It was the blue one that's the second highest because the – I don't know why they didn't pick to analyze the highest one in detail.

But a lot of the range of climate outputs that we've been able to look at were heavily conditioned by this sampling of possible futures that wasn't necessarily very closely connected to the way the world was actually operating. And one of the things that we'll definitely be seeing in the next round of assessments is a broader range of possible futures reflecting not only the outcome of what happens if there's no climate possible but what the implications of adding policy on top of the scenarios might be.

I want to say just a couple of things about the IPCC and I know there've been a lot of questions about it recently. The IPCC is the most ambitious, thorough and I think successful assessment of anything that's ever been done. And it's not error free. I think we've seen that from recent events. But it has an amazing number of layers of quality control that assure that errors are kept to a minimum. Certainly I'm doing everything I can to make sure that in the next assessment the errors are as close to zero as absolutely possible.

But it's also important to remember that the IPCC process puts a certain spin on the kinds of results that come out. And understanding the way it works helps see that.

The first is that the IPPC is charged with being a comprehensive assessment. It has author teams that are drawn from all countries and diverse perspectives. It doesn't pick just the part of the literature that the authors are particularly interested in. As an author, one of the things I'm most frustrated in is that my personal papers aren't that prominent in the assessment. You know, it really has to treat everything, whether it agrees with the paradigm, whether it doesn't and assess that.

The second thing that's important about it is that there're multiple layers of monitored review. For the chapter that I was responsible for last time, 20-page chapter, first round of expert review yielded 250 pages of expert review comments. Second round of review, another 250 pages of expert review comments.

So by the time the chapter has gone out to every self-identified expert on the issue and come back, it should be the case that all of the relevant literature has been identified and the errors have been identified.

There are individuals whose sole job in the evaluation process is to serve as an independent monitor of this review process and make sure that the author teams have responded appropriately to all these comments from the community. It really shouldn't be possible for errors to sneak in.

And I think that where we've seen errors, for example, with the Himalayan glaciers in the AR4, there clearly was a breakdown in this phase of the process and insufficient engagement of the broader scientific community to really allow the IPCC to meet its mandate.

The third thing that's really important about the IPCC and especially important if you what you want to understand is how to think about the IPCC assessment's relative to the latest science is that in the summaries for policymakers – these are the documents that most everybody's seen as sort of 20 to 30 pages from each working group about what the key messages are – following all these layers of independent monitored review, all the countries of the world approve the summaries for policymakers word by word. You guys are the plenary approval meeting. There're about anywhere from 120 to 140 countries represented.

If we're starting the plenary approval process, I put the first line in the summary for policymakers – warming is unequivocal – up on the board. And I say, does anybody have a problem with this statement? And I don't move on from that statement until there's not a single member of the plenary that's comfortable that that wording accurately reflects the underlying science, by consensus.

You know, you think about the political process in the United States and ask what we can produce by – I guess it's not supposed to be a political event but this consensus standard is incredibly high standard for the group to meet. And what it results in is conclusions that are really incredibly measured and incredibly deeply supported by the underlying science. And it also means that the IPPC doesn't really have the opportunity to take an activist perspective or to take a very conservative perspective on it.

Basically the challenge of consensus approval means that you sort of get locked into what everybody can agree as what the science says, a very tight boundary around the kinds of statements that could come out. And I'm important to read the IPCC reports as reflecting this process.

I want to say just a couple of things about impacts and I'm going to focus on impacts that have already occurred and ones on North America. But the thing that's so challenging about impacts is that it's very likely that impacts will unfold in a way that has unexpected components, where different kinds of impacts are interacting not only with each other but with other dynamics in society that may make them simpler to deal with, in many cases it will make them more complicated.

Big spatial and temporal variability in where the impacts occur and it's very likely that the regions that are most vulnerable, where people have the least economic and social resources to deal with impacts where we're going to see the greatest problems.

And it's also very likely that kinds of impacts that are difficult to extract from the scientific literature are going to create unusual problems and a good example is that very little is known about the relationship between climate change and large migrations of humans and the implications of that for military security.

And IPCC really doesn't have anything to say on that because there isn't a scientific literature. But from a citizen's perspective, it seems like that that represents a genuine concern that it's hard to leave out of the picture because there's not a scientific literature on it.

I'm going to mention just a couple of impacts that I think are important. Mike already mentioned sea level rise. The top panel is a picture from Stefan Rahmstorf with the IPCC estimates of seal level rise shown in the grey band and the actual trajectory of sea level rise following the highest curve. I don't know how clear it is on the figure. But basically, the actual trajectory of sea level rise beginning in 1990 has consistently exceeded the estimates from the IPCC.

That's a little more clear in the bottom panel with sea level projects where the IPCC range is the solid blue bar. I guess it's to your right of the panel, and estimates from the Rahmstorf model, which is an empirical fit to past data, are shown in the grey ban with outcomes for different models on the dashed lines. And you can see that an empirical model says that the IPCC estimates which don't account for the dynamics of ice sheets don't reflect the historical or the most likely future outcomes even though it's very consistent with the sort of very measured careful approach that the IPCC needs to take.

Okay. Why is it dead? Okay. I got it. Somebody did something to me. Okay. Mike also mentioned heat waves. It's an interesting figure from the recent science paper by David Battisti and Rosamond Naylor and it simply says, you know, if we take the average of all the climate models that were run in the IPCC "Fourth Assessment" report and say, well, how shall we think about summer temperatures relative to historical means?

And the way they did is they said, okay, in the period from 2008 and 2100 what's the frequency with which the summer temperatures are as high or higher than the warmest temperatures in the historical record? And in this figure, anything that's in the red colors has 90 percent of the future summers are warmer than the warmest on record.

And you can see that for this A1B scenario which is one of the kind of the middle of the road ones, not not at all what we've been doing over the last dozen years, a very large fraction of the world has – essentially every summer is hotter than the warmest summer on record and there's very little of the world that doesn't have at least half of the summers hotter than the hottest summer on the record.

Wildfires is another area where increasingly the science is well understood. This figure from a recent paper by Tony Westerling and colleagues shows the relationship between wildfires in the western U.S. and summer temperatures. Basically what Westerling was able to demonstrate was that the very strong control of wildfire probability based on the length of time between when the snow melts in spring and when it snows again in the fall. Oops, I'm sorry.

We have a good projection of where droughts are headed. One of the frustrating outcomes of the latest round of model analysis is that in general the expectation with precipitation is so we've got more rain where it already rains too much and we've got less rain where it doesn't rain enough.

In this figure you can see that the projected – the yellows and reds are projected decreases in precipitation focused on the southwestern U.S. The projected increases in precipitation are the blues and purples. They're focused on the northwest where if anything, the problems we have with floods are already great. Worldwide the same pattern is true that it's the areas that have lots of precipitation that tend to get more, the areas that don't have less.

And of course, the important change in precipitation is that you tend to get more of the precipitation in extreme intense events and less in the sort of everyday a little bit of rain type events. This is a historical plot of the change in the frequency of precipitation events that are in the highest 1 percent and you could see that especially in the northwest there's been quite a dramatic increase in the amount of precipitation that occurs in these very heavy events.

In closing, I just want to mention one other important part of the climate picture and it concerns processes that feed back from natural systems to drive the future of climate. You know, we've already talked a lot about the way human force climate but it's important to recognize that the earth is a responsive system with lots of different kinds of mechanisms that could be activated.

And one good one that's increasingly well understood is that a warmer climate particularly with changes in precipitation in the Amazon could result in decreased growth of the Amazon rainforest, increased susceptibility to wild fires and an increase in the release of carbon. Essentially what we're doing is turning Amazon rainforests from a carbon sink to a carbon source.

This is a map from a recent paper showing, at least on my screen it's not very clear, but it shows the distribution of carbon sinks and sources in the Amazon and the top figure in the time before 2005 and during 2005 when almost every place that had been a sink for carbon turned into a source.

And it is indicative of a possible future in which we could see a large scale source of carbon emissions from the Amazon resulting in basically a transition from that part of the world acting as a carbon sink to a carbon source meaning that if we want to hit a certain missions target, we need to work a lot harder in order to compensate not only for our historical emission but for a new source of emissions from this process.

Finally I want to show one last slide and it's a characterization of our current uncertainty about climate and it's extremely important to know because the distribution of possible outcomes is not symmetrical.

I know that's a complicated scary sounding term but what it basically means is that the probability that we're wrong about the sensitivity of climate to what we're doing has a much longer tail on the high-end than it has on the low end. There's a lot of uncertainty in climate and that needs to be acknowledged.

We need to view climate change as a risk management problem but the fundamental nature of the climate system means that the uncertainty is shifted as in this figure where even though we think the most likely sensitivity of climate to a doubling of CO_2 is something in the two to three centigrade degrees. There's a significant probability that it's not two to three but that it's five, six or even seven degrees and there's almost no probability that it's less than about 1.5 degrees.

As we think in terms of a risk management framework, we want to be thinking about avoiding impacts that could occur if it turns out that we're wrong at the high end as well as if we're wrong at the low end. I'll stop there. Thanks very much.

MR. ROMM: Thank you. I'm going to ask a few questions to stimulate discussion here and then we'll open up to questions. Let me, I guess, build off what you just said, Dr. Field. What you're saying is that the worst case scenario, the plausible worst case scenario is of how much warming we might see this century is considerably higher than people have been talking about.

So I guess I'm wondering what you think the implications of that are, what should be the takeaway from the fact that there are very plausible scenarios of exceedingly high warming, because this after all is just the sensitivity to a doubling of CO_2. On our current emissions path, as you noted, the high-end scenarios are tripling of CO_2 and bordering on almost a quadrupling which is the highest and the A1-F1. So if you were to combine the high end emissions with a higher sensitivity – so I just sort would be interested in hearing your thoughts on that.

MR. FIELD: You know what, I think that the IPCC has been incredibly careful to sort of present central tendencies of expectations. It's a very reasonable way to go. But with almost everything else in life, we take more of a risk management approach.

When we get into our car, we make sure that we have insurance even though the probability of an accident is hopefully not very high, at the very, very low end. When we make investments we try and make sure that we look at the downside as well as the upside.

And it seems to me that when we make smart decisions about climate, we need to be really acutely aware of the fact that these uncertainties do admit the kinds of probabilities we're talking about, about sensitivities being much higher than the central one. That's not inconsistent with any of the models and it's just saying that's where the science puts us.

The other thing that's really important to remember about the risk of these large amounts of warming is that the larger amount of warming that occurs as a result of human actions, the more likely it is that we trigger some kind of biospheric feedback that locks that change in, that we end up crossing some kind of a threshold or tipping point.

Such a tipping point might be large-scale conversion of Amazon rainforest to savannah resulting several hundred billion tons of carbon to the atmosphere. It could be the initiation of large-scale melting of Arctic permafrost releasing several hundred billions tons of carbon to the atmosphere.

None of that's known with certainty but I don't think it's wise to approach the problem as a risk manager without acknowledging that those are part of the environment that needs to be acknowledged and needs to be understood. If anything, this uncertainty is the strongest motivation for continuing active work and understanding climate and all of its components.

MR. ROMM: Mike.

MR. MACCRACKEN: Well, I'd like to say one thing. One is to give you a sense of scale of what happens. If you take six degrees which is sort of one of the numbers towards the end out there, if you go six degrees cooler, that was what the global average temperature was during the glacial periods when a couple of miles of ice was covering the northern part of North America.

But there's a huge difference. It doesn't sound like six degrees Celsius is all that much if you're moving from Syracuse to Phoenix or something. But it's a tremendous difference for the earth as a whole. If you go six or seven or eight degrees warmer, that's like what it was during the cretaceous which is the period greater than 65 million years ago when sort of dinosaurs roamed the earth and you sort of had palm trees up along the high latitudes of the northern pole. And that was a time when we think the CEO concentration was maybe three to four times what its present concentration is. So that gives you a sense of things.

I think it's also important to say it's not just temperature. I mean, temperature you think, oh, well, maybe I can have more air conditioning or something. But the environment experiences it differently.

So if you go one degree warmer or two degrees warmer as it was during the last interglacial 125,000 years ago, about half of Greenland was melted and that means sea level was – sea level was sort of thought to be four to six meters so whatever 12 to 20 feet or so, higher than at present. That is you can find elevated beaches. And if you go drilling in Greenland, you don't find ice older than that period for the southern half of Greenland.

So a few degrees doesn't sound like much but for the environment it's a tremendous amount and that's, I think, why when Chris talks about risk we really do need to evaluate the risk of what we're doing.

MR. ROMM: Yes, and I guess I would just add that I think there's been a bit of confusion to the public from the IPCC. As you've said, the IPCC presents a variety of emissions scenarios and figures out the spectrum of impacts across those scenarios and reports them and I think that creates this confusion as to what will happen just in the scenario where we don't take any action and that can lead to the very high impacts that you described.

I guess I would like to hit a little bit on the sea level rise issue because I think it gets to this issue of the – won't say conservative nature of the IPCC but the constrained nature of the IPCC.

A few years ago – I mean, I heard Richard Alley give a talk – the IPCC and the consensus was that neither Greenland nor Antarctica would lose much mass this century. And now they already are, as he said it, almost a century ahead of schedule.

And in the 2007 report, the IPCC noted that glaciers can disintegrate faster than simply melting when you heat them up through water flowing down to the base of the glacier in the summertime and lubricating the glacier and causing the glacier to accelerate. So there have been a number of studies in the last two or three years since the IPCC which suggest that sea level rise could be three, four, five, six feet this century.

So I guess I'd just sort of be interested in commenting on how it is that the IPCC came to decide not to factor in these ice dynamics and what the literature now says and sort of what you think will happen.

MR. FILED: Let me say one thing that's important for people to remember about the IPCC. I think the historical dynamic is that the IPCC started out answering the question of whether climate change is real and they wanted to make sure that all of the statements were really tuned in a way that let the stakeholders extract maximum value with respect to that question.

And I think in the future we're really seeing kind of a transition to, saying, well, what's the information that stakeholders need in order to make good decisions. And if you're trying to say, is climate change real, a natural way to pursue that is to say, well, what are the parts of the system that I understand well enough to write out, carefully define physical model for?

Ice sheets are incredibly complicated and I talked about a lot of the reasons that they're complicated. And it's still the case even with lots more observations and lots more science that we don't have something that the community agrees on and say compelling physically based, highly validated model of what's going to happen to ice sheets in the future. I think what we see is a broad range of possibilities.

And in the 2007 report, the IPCC decided to focus on what could be constrained with highly understood quantitative formulations and it didn't include this big range of other possibilities. Science is rapidly moving beyond that and I think that we will see more sophisticated, a richer treatment of ice sheet instability in the future but I think it's also important to recognize that this is a very, very complicated topic and the smart way to think about in the future is going to continue to be to recognize that there is an important range of uncertainty.

MR. MACCRACKEN: I mean, I agree a lot with Chris. I mean, the trouble with the ice sheets and trying to model things – and I was a modeler by training – is you don't have any examples where we have good data to compare your model against. I mean, you can compare it against the relatively limited ice stream coming out in one place and people have tried that and sometimes the ice stream goes faster and sometimes it goes slower and other things but you don't have – it's very hard to have – to find a dataset to use to do that. And so people are sort of suspicious of models and the modelers are sort of cautious. You don't know how to verify it.

What we have in the past is some evidence from the geological record. I mean, during the glacial period, 20,000 years, ago, sea level was lower by 120 meters. So you might sort of say, well, if I do it linearly, each degree is about 20 meters. If you go to the cretaceous when there was basically no ice on earth, we have about 70 meters of sea level stored in the ice right now so presumably all that was down. So it's about 10 meters per degree but the problem is we don't know how fast or how long that takes. And that's a huge issue.

I mean, if it's going to be that Greenland melts over 1,000 or 2,000 years, that's different than if it melts rapidly over a few hundred years. And so there's a real challenge here and this is going to be an area of – as Chris was sort of saying. This is going to be a huge area of risk that it's not going to be possible to get certain information on in the near term. We can make projections but there's always be a range of uncertainty.

MR. ROMM: Let me follow up on one point that you said, Dr. Field, which is the issue of the carbon cycle feedbacks which I guess is one of your specialties. It seems in the 2007 IPCC report for the first time there was some serious attempt to calculate what these feedbacks would do.

And by feedbacks I'll just say when we emit carbon dioxide, some of it goes into the atmosphere, some goes into the ocean, some goes into the soils and vegetations. Some of the sinks can saturate. You can lose vegetation. You can have wildfires. That's sort of one set of carbon cycle feedbacks. Another is one that you briefly alluded to and I hope you'll talk a little bit more about which is the tundra which may be the one of greatest concern.

The tundra is the permafrost which isn't very perma anymore. It's kind of like a frozen locker of carbon and it contains as much carbon, a massive amount of carbon as much as the atmosphere does and could give off that carbon in the form of methane which is a highly potent greenhouse gas if it melts. And as the IPCC calculated the impact of such feedbacks, it constrains the amount of emissions that we can emit this century if we want to stay on a certain pathway and avoid a dangerous warming.

So I guess I'd just sort of be interested in both of your comments on the tundra and the carbon cycle feedbacks.

MR. FIELD: (Off mike) – that we basically have had a huge subsidy in terms of our emissions for carbon. For every ton of CO_2 that we release into the atmosphere, about 55 percent of it doesn't stay in the atmosphere. It's taken up at least temporarily by some kind of a sink in the oceans or on land and currently it's about half in the oceans and half on land.

We understand some things about the likely future dynamics, what's likely to cause the ocean sinks to change for the future and the projection is that they will decrease in intensity. Land is a little bit trickier because we're not 100 percent sure what's the relative contribution of all the mechanisms that are causing sinks on lands. Some of them are natural processes, things like the faster growth of forests and response to the elevated CO_2 in the atmosphere which acts like kind of a fertilizer. But some of them are consequences of things we didn't – (inaudible).

North America and Europe were mostly deforested around 1900 and large areas of forests have grown back pulling carbon dioxide from the atmosphere. In the 20th century, we build a vast numbers of reservoirs and those reservoirs silt in which is an environmental problem in many areas that silt is typically organic matter rich and storing a large amount of carbon.

So it's hard to make an accurate estimate of what's going to happen to the future of this important subsidy that we've had in terms of carbon uptake from terrestrial ecosystems.

As Joe mentioned, there are at least a couple of areas where potentially very large stocks of carbon are at risk as a consequence of passing some kind of a tipping point though we don't know exactly where it is and that's the reason that this risk adverse approach I think makes sense.

One is in the world's tropical rainforest where we know, for example, in the Amazon that relatively small differences in precipitation can convert a forest that's essentially inflammable to one that's flammable. And once a forest, tropical forest burns a few times, you tend not to get a tropical forest back.

There's a big body of literature now for the Amazon in particular indicating that once removal of forests covers more than about 40 percent of the areas, precipitation patterns change resulting in more of a savannah like precipitation and potentially making it impossible to get forests back. That's kind of a classic tipping point.

Until now, humans have emitted something like 500 billion tons of carbon in the atmosphere by deforestation and combustion of fossil fuels. That's really a lot. The amount of carbon that's frozen in perma frost is probably about 1,500 billion tons, about three times as much as we've emitted through all of human history.

Large amounts of that permafrost are in the coldest parts of the world unlikely to thaw in the near time but quite a lot of it is in areas where the climate has already warmed dramatically and where future dramatic warming could result in losses of large amounts of permafrost. Some of the climate model calculations have more than half the permafrost disappearing by 2100. How much disappears is of course a function of how much the climate warms.

And one of the things that's most intimidating about the high latitude carbon stores is that we don't really know at what point they begin to lose so much carbon that we really can't shut it off.

There was a really interesting series of papers published in 2008 showing that metabolism of this carbon which is actually quite easily decomposed – it's basically easily decomposed plants that were frozen 20,000 to 40,000 years ago generates heat and that in many areas of the world, especially the windblown – (inaudible) – sediments across Siberia which hold more than 500 billion tons of carbon, you can actually create conditions where the decomposition of this material occurs fast enough so that the heat generated by the decomposition sustains the thawing, even if the temperature doesn't continue to increase.

And that represents another one of these classic tipping points where once you reach a certain level of decomposition it's not clear how it will get shut off. I'm not saying that we're headed for either of those points. We don't know but we do know that they represent a non-insignificant amount of risk as we face the future.

MR. MACCRACKEN: I guess what I'd add is we've seen this feedback seemed to work in the past and that's unfortunately, however, caused some confusion in the public about it or raised some concerns and that is it worked in the past during the glacial cycling. The main timing of glacial cycling is controlled by sort of changes in the shape of the earth's orbit and how much solar radiation reaches each hemisphere at different times of the year. But that isn't enough in the models to drive the ice ages, the ice age cycling.

What's needed are some feedbacks and one of them is this carbon feedback and you see that because you see the CO_2 concentration changing naturally during the – in the ice corps records during the glacial cycling. And in the glacial period what happens is the orbital elements change in a way that start this warming occurring that starts up this carbon feedback which causes more warming which releases more carbon and you get that going.

That's been taken to, you know, be interpreted sometimes by people who are sort of skeptical of all of this that oh, the warming came first before the CO_2 so that disproves all of our thinking. Well, no. This is a feedback process. And what's clear is once you change the CO_2 concentration in the atmosphere, however you do that, you get some warming.

Right now we're putting it in for fossil fuel use factor in the glacial cycling that was coming because there was some warming due to overall elements but in both cases, once you got the CO_2 and you started doing that warming.

So we think we have a consistent understanding. And understand that this feedback is important and has worked in the past and that's why we get worried about his sort of upper end that Chris is talking about.

MR. ROMM: Great. Before we open it up to questions, let me ask a couple more about the IPCC. I'm wondering – obviously, there's this distinction that I think you drew between these lengthy technical report which is like 1,000 pages long and the summary for policymakers which are sort of much more carefully vetted. It is – and that is what policymakers presumably base their decisions on. I'm just wondering if you'd sort of discuss that a bit more about the distinction between those two.

MR. FIELD: I think of the IPCC process as producing something you can think of as a pyramid of information. The reports are intended to be comprehensive. Everything is considered at the technical level, things that are of highest quality, things that are of lesser quality. And the idea is that the vetting process gets to be more and more strenuous as you move up to the key messages that are presented in the increasingly refined documents like the technical summary and the summary for policymakers.

Our goal in the IPCC is that there be 100 percent error-free analysis all the way from the base all the way up but just as a consequence of the amount of human capital that can be invested, you know, all the IPCC authors are volunteers who have day jobs, the intensity of the scrutiny definitely gets to be greater as you move up this pyramid. All the challenges of recent have been to the information at this base level where it's just an internal primary processing of all the information that's out there in literature.

And it's extremely unfortunate in the case of the Himalayan glaciers, for example, that there wasn't sufficient vetting to identify one poorly substantiated number. And I think that the process definitely failed there but it did work as that information was filtered up toward the key messages that were presented to the world's governments and the world's stakeholders in the summary for policymakers.

MR. ROMM: Yes, the mistake did not make into the summary.

MR. FIELD: That's correct.

MR. ROMM: Mike.

MR. MACCRACKEN: Yes. I mean, I think it's important to understand that each of these chapters is a big topic. The topic in the Himalayas was all of Asia so you've got to cover everything in Asia in 25 pages. The authors aren't going to know everything. And so somehow they didn't catch it and it got in. But the review process is supposed to work. People have talked about some of the review comments but what has been surprising to me is who didn't comments.

In particular, when we were running the U.S. government process during the first – at least the second and third assessments where I was involved, I mean, there was a program manager assigned to every single chapter to make sure that chapter got reviewed and we tried to make sure 10 experts reviewed its chapter and then after it came back, we sent it back to those experts and asked, did they pay attention to your comments and how did it go. I mean, it's interesting that there is no comment from the U.S. government in the review comments here. I don't know if they didn't have a person reviewing it.

Part of the U.S. government review is to make the chapter available through the federal register. We used to do it slightly differently but now it can be done electronically or something like that. And so the chapters were available for public comments. And so everybody else could have reviewed it and somebody could have caught it that way. Again, there doesn't seem to have been any comment that way. So part of it has to do with how different countries were running review processes. You really have to help the authors out. I think it was surprising that countries in the region didn't do it.

I wanted to say just something on the summary for policymakers because I think it's really important and there are some differences here. These scientific chapters are written as scientific reviews and we talk about uncertainties in those chapters the way scientists talk about it so that we want to have very, very high levels of confidence before we come out with a finding and we do that because you don't want to have errors like – (inaudible) – by making a mistake or something like that causing birth defects or something. So in this sense we talk that way.

But when you talk to policymakers, they work in a different frame. They work in a relative risk kind of frame. Is it more likely this than that. The world and business and everything couldn't exist if you made decisions the way scientists do because you'd never get in and drill an oil well or something. You'd never be certain enough to do that.

So there's been this lexicon that comes together about how to explain it. The example – some people say – there are some skeptics who say, you shouldn't even do it. You should just give the scientific reports to the decision makers. You shouldn't have this dialogue.

I think it's important – and the analogy I sort of use is a cancer patient going in to see their doctor. The doctor could say, okay. I'm going to give you the reviews papers that are done by the National Institutes of Health. You figure out what your treatment is going to be. Well, you wouldn't be very happy with that. That isn't really speaking to you in any terms.

Then there's technical summaries that IPCC does and that's a lot like the American cancer guidelines for what your treatment should be and the doctor could see, here are your guidelines. You figure out what your treatment should be. And you say, no, no, no. I want to have a conversation with you about my situation, about what these terms mean for me.

And that is exactly what the summary for policymakers is. It's a documentation of that conversation between the scientists being rigorous but speaking in terms and ways of expressing things that people over here, the public can understand about, well, this treatment is a little bit better and more likely to succeed than that one and to give the best estimate. So it's an important – it's a difficult process. You'll have problems a little bit in it but they try very hard to make it work.

MR. ROMM: Let me just ask one last question which I think, for those of us who follow this may be the biggest and most surprising issue. It turns that the IPCC technical reports don't just summarize the peer reviewed literature but they summarize – they also include things called the (grey ?) literature and that's where this Himalayan glacier mistake of the Himalayan glaciers as being largely gone by 2035 came in. So I'm just like – can you explain how the difference between you from the literature, how the IPCC decides what non-peer reviewed literature can be factored in, and then, how do we improve things in the future?

MR. FIELD: Yes. Well, the IPCC has clear guidelines on use of non-peer reviewed literature. For anybody who's an aficionado it's NXB of the IPCC procedures and they're available online.

The science moves we hope progressively but in sort of a confusing way and a lot of things that are published in the primary peer reviewed literature, the regular journals, turn out to be correct. A lot turn out to be incorrect either as a result of the data being difficult to interpret or the sort of conceptual framework in which they were analyzed not being 100 percent valid. And that's the reason that the IPCC process is so important is it provides a way to do comprehensive look back and see what kinds of results have stood the test of time and what haven't.

And with lots of the topics that the IPCC addresses, the regular scientific journals, there's anonymous peer review provides sufficient foundation in order to provide a complete analysis. But there are lot of other areas where the peer reviewed literature just doesn't provide the information that's necessary or where a lot of work doesn't end up in regular scientific journals.

Lots of things that are associated with the issues surrounding adaptation, user experiences of what kind of steps can decrease vulnerability to people or communities to certain kinds of climate change. In a number of areas – insurance is actually one where private companies have done a lot of the work on modulating insurance philosophies in the context of climate change. Valuable information.

And the question is, well, how do you extract that value for the IPCC and it's something – and IPCC has struggled a lot with. The way I think about it is that the peer review process that leads to publications in scientific literature is a critically important first step in the quality control. IPCC still needs to do a lot of quality control on top of that. When non-peer reviewed literature is used, the responsibility of the whole IPCC enterprise, the authors, the reviewers, the review editors is notched up as a consequence of not having access to that incredibly important initial quality control step.

With the Himalayan glaciers, I think we see a failure at all three of those levels to not impose the extra level of scrutiny and quality control that the IPCC procedures require and I think common sense requires for dealing with material that doesn't appear in non-peer reviewed literature.

Given the range of subjects that the IPCC has been tasked to address, it's hard to imagine how it could do that successfully if it didn't have access to literature beyond that in regular scientific journals. But it's also hard to imagine how it could be successful without taking incredibly seriously this responsibility to do extra careful assessment and then an extra careful assessment on top of that of everything that's not in the standard peer reviewed literature.

MR. ROMM: Mike.

MR. MACCRACKEN: I'll just only add that things are different around in different countries of the world. I mean, there are different traditions about how you do scientific literature. This has sort of been in part a Western tradition in some sense. In some countries they have many more scientists in their government laboratories and so you get government laboratory reports.

Also as you work through the IPCC process from working group one to two to working group three, you start to get to things where the tradition is quite different.

When you're talking about advances in various energy technologies and options, that can be sometimes in corporate reports or something. When we were doing the U.S. government review process, we would get a lot of very valuable comments from industry where they were providing specific information about how something worked and it was an industrial report or something like that.

And so I agree with Chris. You can't imagine trying to do it on just what's in the technical literature. You have to rely on this but you have to figure out how to make sure the review process is really careful in looking at that.

MR. ROMM: Well, that's great. And let's open up to questions. We start with journalists. Are there any journalists here who want to ask some questions? Please identify yourself.

Q: Eli Kintisch with *Science* magazine. I wanted to ask Chris about a proposal that three scientists recently published in *Der Spiegel*. This was – it was Roger Pielke, Richard Tol and Hans van Storch. They said your procedures don't allow for an official way to offer corrections the way that a scientific journal offers. But when I talked to you the other day, Chris, you told me you don't feel that the procedures need to be changed. Do you think there should be a more official ways to issue corrections?

MR. FIELD: Well, I think that in general, the IPCC procedures, if they had been thoroughly and comprehensively applied would not have allowed the problem with the Himalayan glaciers to come through. There are a number of areas where, as I think as an individual, not speaking here for the IPCC, where I think we can do a much better job in the future. I think that as far as I know, the vast majority of those won't require changes in the procedures.

It's things like making sure that authors are comprehensively trained, making sure that authors do a good job of identifying where contributing authors need to cover topics that haven't necessarily been covered, making sure that we have a systematic approach to ensuring that relevant expertise is available to look at the regional chapters which are in some ways mandated to cover this vast range, every topic that's covered in the physical climate, in the impacts area and in the mitigation has to be covered at a regional scale by a small group and how can they be supported to do their work more effectively.

The issue of correcting errors is one where we may need a change in the procedures. And the way – the challenge that we face in the IPCC – we've done errata before like if the decimal point comes out at the wrong place in a number or if there's printer's error.

Where there's an error of interpretation, it's complicated to think of what an effective error correction mechanism would even look like. We have one error correction mechanism in place which is that we revisit the topic in a new assessment and go through all the layers of the analysis and approval. And there's some sense of which that's a right way to do it but it obviously doesn't meet the needs of the stakeholders for a timely response.

So what could we do that would provide a more timely way to revisit topics where as a result of increased information or a result of discovering an error, something really needs to be revisited in a timely way.

And without expressing a personal opinion on whether we need to have a change in the procedures, I should say it's unclear to me how we can come up with something that would meet the full range of stakeholder needs in a comprehensive, timely and a not overwhelming way.

MR. ROMM: Yes. Mike. Sure.

MR. MACCRACKEN: I agree with Chris but I guess I do have sort of one suggestion which is based on how the U.S. government has done the review process. I mean, IPCC has had a tradition where it's saying this is sort of a close hold document; it's not certainly for the media to be quoting out of because it's preliminary and not finalized.

And so they've been mailing to selected reviewers and selected organizations that are members of that. When we were going through the second assessment review process with the U.S. government we basically got asked by some organizations who weren't affiliated with the IPCC but who were very active in the field, well, how come that organization can have copy to review and how come we can't? And there was some professional association, I think. And we never came up with an answer for that. And so that's why we went to just trying to make it available in a federal registered review process.

IPCC has been a little uncomfortable with that because we didn't sort of try and say, well, only U.S. citizens could have it, because we didn't want to have to try and go through citizenship and stuff and U.S. citizens can be anywhere around the world and everything was too complicated. So we basically made it available. I think what you just have to do is figure out how to try and strengthen the review process a little bit and I think being a bit more open with it so more people can look at it would possibly help somewhat.

But I think – and I agree with Chris because IPCC only speaks through its assessments and how you figure out a process where it's going to be as authoritative in the correction as it is in the assessment I think will be hard to figure out.

MR. ROMM: Yes. I guess I would just add, as someone who's not involved at IPCC that the related issue is that you have these monster – in one year you've got thousands of pages coming out all at once and we have to wait from 2007 to 2014 or 2015 to get a restatement of the recent scientific literature on sea level rise. So corrections go in both ways. There are corrections in one direction and then there's corrections in another direction and I think the IPCC really has to figure out how to take smaller nuggets and be more timely.

MR. MACCRACKEN: But special reports can do that. I mean, they could do a special report on that and they are doing one (on extremes ?) and they're doing some others and that's happened before. I mean, when they wanted to do aircraft and climate change or they wanted to do some other things. And so I think there is a mechanism to say, okay. If it's a really significant issue or something, go after it and do a special report.

MR. ROMM: Another question from a journalist. All the way in the back, very, very last row there. Yes.

Q: Edward Greuder (ph), Sunshine Press. Pardon my voice. In the wake of the earthquake in Haiti, we heard from a very prominent American broadcaster on matters scientific particularly having to do with cosmology who gets ratings that are way higher, many times higher than Bill Nye, the science guy, who pronounced that the earthquake was the result of a deal with the devil made by the people of Haiti a couple of hundred years ago.

Given that many, many more times the number of Americans who understand what – (inaudible) – believe in angels, how do you get scientific information accepted not past the quibbles of other reasonably rigorous scientists but to the American public that is disbelieving in a lot of what it hears about climate and does believe Pat Robertson and his deal with the devil.

How do you communicate science to the public in a way that given also the fact that there's a lot of money to be made and lost based upon the decisions that are made about climate policy and saw a lot of reason to invest in disinformation about it, how does the scientific community get solid information past this cloud of confusion?

MR. FIELD: You know, it's a terrific question and I don't claim to have the answer but I'll tell you something that I find has worked for me is that, you know, in order to work effectively as a scientist, I need to stick to what the science says. There are a lot of people who are better looking than me and more compelling spokespeople and it's not worth it for me – I don't have the ability or the backing in order to be a promoter of the science.

What it seems to me is that in order to have society effectively take advantage of scientific information, there really need to be three things. You know, one thing is that there needs to be a recognition that the science process is a uniquely powerful way of learning things that we wouldn't have the technologies, we wouldn't have the understanding that we have today unless it was built on science. The fluorescent light bulbs or the computers – that's unique contribution of viewing the world in a technical way. Not that science should dominate every argument but it needs to have a place at the table.

I think the second thing is the recognition that there needs to be a part of society that's focused on helping the less technical parts of the society understand what science says and what it doesn't say. And that's a partnership that comes from the media. It comes from – it comes from concerned citizens.

You know, and I think the third thing is that it's important for the general public to not reject the idea that they can be sophisticated participants in a discussion about what the future is about. Sure, I don't need to tell that to the people who are gathered here today but unless you make an investment in figuring out what's important and what's not important, it's really hard to make good decisions.

MR. MACCRACKEN: I guess I'd say a couple of things. One is it's important to understand that the scientific process, as scientists are working day to day, is focused on trying to resolve disagreements and so they're always going to be talking about things they differ on. If there's something we all agree on, what's interesting about doing that? You're not advancing understanding by focusing what we all agree on.

And so as more and more science is done over the years looking at more and more detailed nuances and things, you keep having people come up and say, oh, I think it's this, I think it's that. And so there's this sort of adage that goes – you know, the hard thing about being at the cutting edge is keeping ahead of the blade. I mean, we're sort of going back and forth.

And that's why I think in explaining it to the public and why I tried at the start was to go back to – there are a few basic issues that come up for considering this issue for policymakers, these basic findings that have been solid for a very long time and they basically indicate we have to do something about it or we're going to have major change. We don't know exactly what's going to happen in particular years or exactly this place. But we're taking a huge risk and we have to do something about it.

Now, the way we try to do that in the national assessment to try and really get to people and which I think has to be done, is you start thinking about climate change at the global scale and work down, it's hard for people to sometimes think that way. They want to know what does it mean to me?

And so we basically had a regional distribution of workshops. And so you looked at what it meant in each area and it means something different in the Great Lakes than in the Rio Grande basin or in the Great Basin or any of these other places and you basically get down there and what we did was ask them, so what's going on? What are the changes occurring? And then look at how climate change might affect what's going to happen – it might add to it or simply moderate it or something or introduce new stresses – and try and figure out win-win solutions in the context of what they're doing. So it's not treated as a separate issue but it's integrated with all of the issues that everybody is dealing with. And so I think we need to get back to that.

We were trying to start that process in the 1990s and ended – (inaudible) – because they got back to focusing on so exactly what is climate change and get out back out in the regions and try and help people understand. And we found that they could understand that there's some range of possibilities of what can happen. That's what local people deal with all the time. And so don't hide uncertainties. Don't wait to do it. Don't say it's too uncertain to talk to them about it. Go out and talk to them about uncertainties and about what is expected and let them evaluate if it's enough information to take action or not.

MR. ROMM: I would just add the failing is – I think scientists have a challenge – I also think the media has a responsibility here. The media has been shedding science and environment reporters and I think the media has to think very hard about how it is going to do a better job of communicating this and the science community has to figure out how it's going to do its job in a world where the media is radically changing. I'll just say for the perspective of the Center for American Progress, we set up ClimateProgress.Org and Science Progress to help communicate the science.

And I think that we're going to need a lot more channels. I think the scientific community is going to have to figure out how to use the new media channels to get to speak – communicate directly to the public and not rely on the general media. Maybe two more questions. Back – from journalists. We got over there on the –

Q: Rick Peltz, Climate Science Watch. I think the IPCC is really an essential resource and we now have the beginnings of what I think will be an ongoing campaign by the Global Warming Disinformation Campaign to discredit and delegitimize the IPCC. And that business with the Himalayan glaciers is just the start of something that's not going to end.

And in terms of defending the IPCC, I guess my question is apart from whatever needs to be done with regard to the authoring and reviewing process to minimize these kinds of problems in the future, it seems that there's also a problem with communications.

I mean, who is the IPCC when it comes to communicating other than through the published assessment because we had a long period of hemorrhaging with this Himalayan glaciers thing where really the IPCC was essentially Pachauri and his way of handling it basically sucked and did more damage in the cavalier and inaccurate way that he spoke on behalf of the IPCC.

So it seems that there's a – what is this communication strategy for the IPCC leadership going to be to make sure that the public and policymakers see this institution as being impeccable and not in an advocacy mode and without conflicts of interest and highly credible going forward?

MR. FIELD: All the points you make are really excellent ones. I think that the – what you've seen is the fact that the IPCC is run by a bunch of volunteers who do their best and have a rich legacy of integrity to fall back on but are not generally sophisticated communicators and don't have access to a whole bunch of tools that could be activated in other kinds of environments. You're also 100 percent correct that the IPCC was very slow to come up with – well, has been slow, is in the middle of being slow to come up with a comprehensive strategy to the challenges that are being raised.

And personally, that's where I think we need to make our biggest investment now is figuring out how to come up with a comprehensive strategy that helps people understand what the IPCC is, how it works, how it can be sure internally and externally that it's avoided advocacy on important issues and how the integrity of the process can be assured top to bottom. And I think that it's a challenge that has many components that are in the communications domain but it also has components that are in the actual operations of the IPCC domain and personally I'm committed to seeing progress on both of them.

I wish I had a little more leverage on the organization in order to accelerate that progress but the discussions are ongoing and every point you raised I think is a relevant one about the importance of not only doing the right thing but effectively communicating it.

MR. MACCRACKEN: I mean, it seems to me that the problem is the alternative which might be worse. You know, if you basically have the IPCC hire some people professionally to spend their time communicating and packaging things and being there to answer things all the time, then it's going to be seen as an advocate of having a position, of seeking money, or of all these other things we're sometimes accused of.

I mean, scientists – they say scientists are in it for the money in many cases, and you go – no, you don't go into science for the money. You go into banking for the money. And all of these things are done by volunteers are Chris said.

And so they basically – and if you look at it, many of them are coming from the academic community. They don't get much credit for doing IPCC. That's a big multi-authored publication. They get credit for doing the research they've gotten the grant for and for publishing in certain ways and stuff. So often they don't even get credit. I mean, it's an amazing public service that is done. And so it needs to be seen as that incredible process that Chris was talking about at the start.

So I mean, the question is how do you figure out how to make it better but without making it worse. And I think that's a good challenge for the IPCC. I mean, what we've been doing is, I think as the authors of particular things will sometimes be out there trying to speak but they can't speak on behalf of the IPCC as a whole. They can speak of themselves having been in that position and what their insights are but they can't speak on behalf of the 150, 180 countries that are participating in that way. So it is a real challenge to figure out what to do but I think other situations might be worse.

MR. ROMM: Well, I think we're going to have to wrap it up here. I think that obviously communicating science is one of the great challenges of our time. That is why we set up this panel to bring in two leading scientists. So let's please give them a warm round of applause and thank you for coming.

(Applause.)

(END)