

Global Assessment of Vulnerability to Climate Change

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Alex De Sherbinin: My talk is about 50 slides long so I violated every principle of good presentations right off the bat by including so many slides. But there were too many good things I wanted to show you so I'm going to get right in to it and wanted to briefly just describe what season is at the Earth Institute.

First, the Earth Institute is kind of multicenter organization at Columbia University that's focused on science for sustainability and for poverty alleviation. It's headed by Jeffrey Sachs who is formerly of Harvard, special adviser to the UN secretary general. And there's quite a number of senators at the Earth Institute.

We're one of about 20. The biggest center is called the Lamont-Doherty Earth Observatory which is really some of the slides that I'm presenting were borrowed from colleagues who worked very extensively on climate change. I'm not a climatologist. I'm a geographer. My focus is more on the human environment interactions but I'll be happy at the end if there's questions related to climate change. If I'm able to answer them, I'll do that.

Our own unit is really a data in research center. And as I mentioned, we're focused on human interactions in the environment. We have a NASA data center which I help to manage. That NASA data center produces socio-economic datasets that are to be used in conjunction with remote sensing satellite observations that NASA produces.

Part of that project also sponsors one data repository of the IPCC which is intergovernmental panel on climate change which focuses on the stress scenarios, the underlying emission scenarios that are used to produce the climate projections.

So this is an overview of my talk. The focus is not on mitigation so I'm not be talking today about how we might reduce greenhouse gases that contribute to climate change but rather on how we, as a society, can use spatial data and other information to begin preparing for climate changes that are already taking place and are likely to take place in the future owing to increases in greenhouse gases.

So I want to give a very brief primer on climate change. Many of you probably are aware of these facts already but I didn't want to go through all presentation and then have someone ask at the end where those climate change real or is it likely to happen.

So starting in the upper left hand corner, you can see the growth and emissions in carbon dioxide, methane, and nitrous oxide, and if you look at the right, there is the forcing

effects of these different emissions. And SO₂ has the greatest forcing effect in terms of pushing the climate system towards higher temperatures. But methane is right behind it along with nitrous oxide and halocarbons. And then there's some things that are actually having an opposite effect. They are actually reducing the effect of anthropogenic forcing on the climate, and those are things like aerosol.

So, ironically, if we clean up our air by reducing particulate matter or sulfates and things like that, we'll actually potentially be increasing the overall forcing on the climate system. So this is one of those perverse things. But overall, what's happening is you can see these trends are going upward and upward and, simultaneously, we're already observing changes that are occurring in the temperature record. I believe it's roughly 0.2-degree increase or 0.4-degree increase that we observed since roughly the 1970, the climate norm period which is considered roughly 1950 to 1980.

One of the things that we're seeing also is increases in temperature up in the northern latitudes in particular. These temperature increases are even greater than the global mean average that you saw on that last chart because there are differentiations on how the temperature affects at regional differentiations and how temperatures are changing. There are also changes in drought severity and you can see a notable or marked increase in the amount of drought activity subsequent to about 1960.

So one of the things we're already seeing is in the biological and physical systems we're observing actual changes. This was part of the recent IPCC report called the AR4, the Fourth Assessment Report, and colleagues at Columbia University, Cynthia Rosenzweig and others were involved in producing this map or these maps showing--these are only studies that were statistically significant that showed that there were actual changes occurring particularly in the cryosphere which is the ice. So you have glaciation or other ice patterns melting in the spring earlier in some lakes or later icing on lakes and water bodies in the fall in the northern hemisphere.

You have biological systems that are being affected, terrestrial biological systems, so plants are maybe pollinating earlier or later, birds are showing up in places that they didn't show up before because their ranges are changing, and you have hydrological changes like drought and other impacts. And so these are studies that are statistically significant that showed that climate change is actually already occurring.

So let's take a look at future changes. This map on the left of the chart shows different scenarios. And unfortunately, like any area, climate change is not without its use of acronym so basically the A2 scenario is essentially a business as usual scenario. It means that we don't really make any dramatic changes in the amount of greenhouse gases that we're emitting into the atmosphere.

The B1 is a more sustainable scenario, lower emissions. But what you can see and what the common denominator is of all of these, even the constant year 2000 emissions, in other words, in the year 2000 if we just said stop producing more emissions than that year, we continued on constant emissions, everyone of these scenarios results in some

increase in temperatures with the A2 business as usual resulting in a potential global change of almost 4 degrees Celsius by 2100.

The Hadley Center in the Met office in the UK produced some very useful maps that you can access by searching in Google Earth if you're a Google Earth user. And basically, those maps depict regional changes that will occur in temperatures. Both are 20:50, but they actually have a time series so if you're in Google Earth, you could animate the time series and see the changes.

But down here is the scale of temperature changes. And once again, we're seeing-- basically, if you go to 2100, market increases in the polar regions, and then overall, in many regions fairly significant increases of eight to ten degrees, in some cases, Celsius. So that's almost double the Fahrenheit degree equivalent. So, pretty significant changes.

Now, precipitation is much more difficult for the climate model or steam model. So basically, this is telling you in roughly 2020 to 2040 what kind of precipitation changes we'll likely to see. This is actually precipitation minus evapotranspiration. So it's net of temperature increases that will result in higher evapotranspiration.

And what you're seeing basically is that drier areas are tending to get drier. Southwest US, parts of the Mediterranean basin, Southern Australia, very severe, if anyone read the recent National Geographer article about the issues that are going on there; Southern Africa.

You're also seeing subtropical dry zones expand northward so much of--well, Missouri has been there somewhere and you can see that we're projecting a potential change of-- maybe it's not seemingly that dramatic in this 40-year time scale but if you go out further, it starts looking more dramatic in terms of the millimeter change per day.

What happened? Did I already show this? So this is a little thought experiment that I conducted because I realized that a lot of the people that I spoke to really did not have any concept of what a ton of carbon emissions really amounts to. What's a ton of carbon emission? How can I relate that to real life?

So I did. I looked online like anyone could and I looked up and I found that a ton of carbon emission is roughly 400 gallons of gasoline. And so if you look at current per capita emissions in the US, we're up here kind of a stratosphere of about 2200 gallons of gasoline per person. So this is not what you personally are consuming but it's rather what our economy as a whole consumes. And then if you divide it on a per capita basis, that's what you'd get.

And the same can be done for Russia and Japan and China. You see that Japan, with a very healthy, strong economy, is consuming roughly half as much per capita gasoline as we are. And this is essentially petroleum or fossil fuel equivalents that I used. So I converted everything to gallons of gasoline.

But our target needs to be down here around a hundred gallons of gasoline per person planetary-wide by 2050 if we're going to stabilize our greenhouse gas emissions and if we're going to avoid dangers and they're called dangerous climate change. So we've got a huge job to get from there to here. And part of what I hope this kinds of grass can show is that it's not a simple matter; it's going to take a lot.

At the end, if I have time, I'll show some of the emissions, wedges they call them, wedges that are needed to reduce emissions in the United States and we can talk about that a little bit more. What's interesting to note also is that if you divide up on a per capita basis and think about equity or the equity of consumption, some countries actually have to increase their emissions. If you look at Bangladesh and Nigeria, they both actually consume below 100 gallons of gasoline per person per day up for a year at the current time.

So I'm going to transition now and talk a little bit about vulnerability and I see time is going to go by quickly. So I'm not going to go into great detail here but what I mainly want to say is in the old school of thinking, we used to think about hazard impacts as being just an event occurring, and then people basically undifferentiated being affected by the hazard event. What's occurred recently is a shift in the social thinking and a realization that not everybody, the same impact event, does not affect everybody equally.

I'm going to show some slides of Katrina and some other areas of the world that show how that actually works out. But basically, the reason for that is because there's differences in the sensitivity, the intrinsic--your income or your education or other things that each one of us has intrinsically, and also our ability to adopt to changes. So we'll look at that in a little bit through some maps.

Of course, social scientists being kind of crazy and nutty, they create all these wacky flow diagrams. But you'll see is the elements of exposure, sensitivity, and adoptive capacity are essentially the same in a lot of these diagrams if you look at people as a conceptualized--what vulnerability is and how we're going to cope with future climate change.

My main point today is that a lot of these things, a lot of these elements of vulnerability, are actually spatially differentiated. So the climate change impacts aren't going to occur in the same way as everywhere. We saw that from some of the maps I already showed about temperature and precipitation change. The vulnerabilities are spatially differentiated as well and adoptive and coping capacities are also spatially differentiated. And if you take this data and you lined them up in a GIS framework, you can begin to analyze where people are more vulnerable and where they are less vulnerable.

So let's take a look at some current vulnerabilities to kind of say where people more vulnerable today to understand where they may be most vulnerable tomorrow. This is a map that we produced for the World Bank showing flood extents and the highest sort of vulnerability areas for flooding where the work is currently being redone and it maybe doesn't show quite an extreme distribution of flood exposure.

But nevertheless, you see that parts of, obviously, the Mississippi Valley in southeast of the United States are highly vulnerable to flooding, as well as a lot of coasts of China and parts of South America. There's also cyclone hazards which actually contribute to the flood severity but they're not totally related. And you can see areas of the world with highest frequency of cyclone events over this 20--it's a roughly 20-year period over which we collected data. And you see, obviously, the Caribbean and Southern United States and the Gulf Coast being highly affected by cyclone vulnerability.

If you zoom in to the area of New Orleans--and this is a very dry depiction--I went to the film yesterday. It was a fantastic film on Katrina, on the cultural impacts. So this is kind of a dry social scientist, physical scientist view of what happens. Obviously, there's a lot more to what went on with Katrina than what can be depicted in a few maps.

But you have cyclone frequency and distribution, you have some mortality risks that we actually did well before Katrina occurred. And what we did after Katrina is we looked at US census data and we looked at population density in New Orleans, we looked at the percentage of African-Americans in New Orleans, we looked at the percentage of age 65 and older population and their distribution in New Orleans, and these are all elements of the sensitivity of different populations to a potential climate impact.

And then along came Katrina--I remember very well, I'm sure of all you do as well, when Katrina rolled through. And it was just horrific to think of this huge cyclone Category 5 hurricane coming over. And this is a map that sort of combined social vulnerability including a number of variables like percentage of households without cars and things like that per census unit. And that turned out to be a very important variable in the Katrina disaster. If you didn't have your own car, many people were left behind.

This is an example of a map I produced just using that same hazard dataset on the global scale and then looking just at climate-related hazards of cyclones, flooding, landslides and drought. And then I was looking at certain cities and how they were located in those zones of high climate impact vulnerability or hazard.

Another way of looking at this is to look at the difference between the frequency of an event. These are frequency of drought events in Africa and the mortality risk of those events. And what you'll see is that some areas have very high frequency drought but they don't necessarily have high frequency mortality or high mortality.

So that means that there's something about those countries. That they're more resilient, they have greater institutional capacity, maybe they're able to distribute food in a more effective manner to their populations.

Now, if you really to look at vulnerability, you really want to look at a whole range of factors such as socio-economic status, household characteristics, gender, age, social networks, historic inequalities, institutional inequalities, building codes. You could create a long list of vulnerability indicators and I know a lot of colleagues who have.

We basically use, as a proxy, poverty. It's not full and multidimensional like these vulnerability and disease. But basically, it captures a lot of what we want to look at. It's a susceptibility to exposure, shock, stress and risks, and it basically represents a narrowing of coping and resistance strategies, the loss of diversification, restriction of entitlements and the lack of empowerment.

One way we've done this is we created a global map of infant mortality rates. And you say, "Well, great, what's infant mortality rate got to do with poverty?" But it turns out that if you do on a national or sub-national level, income is very highly correlated with infant mortality. And so we created a sub-national map.

It's a little hard to see but it gives you a lot better--even parts of Southern US starts showing up, parts of Mexico, some of these have a lot of sub-national units. You can really begin to see the spatial differentiation; and especially poverty at the lowest income at the lowest end of the income bracket. Those people who are most vulnerable.

And we did some things looking at, for instance, the distribution of poverty relative to drought frequency and growing season classes. And what you see, interestingly enough, is that the non-poor population is clustered much more here in areas of low drought frequency in long growing seasons. But if you take the poor population globally, their population distribution is much more towards areas with shorter growing seasons and higher drought frequency. And so you can begin looking at geographic and geo-physical determinants or correlates of poverty and deprivation.

Here is another thing we did for the Millennium Ecosystem Assessment, and we just wanted to see which of the various ecosystems in the world had the highest levels of poverty. It turns out dry lands had a very high poverty rate here up in the upper right-hand corner. Polar regions, oddly enough, are actually among the most. Maybe it's because Norway and some of those countries and Alaska and Canada are very wealthy.

But basically, if you project population also in those zones in the future, one of the things that's kind of disturbing is you realize that dry lands have one of the highest changes in population density between 1990 and 2000. So they have a very high growth rates, so they're going to be facing some fairly significant strains in the future.

If you look at the area that's affected by drought in Latin America and you just basically look at the poverty rates within those areas that are drought-affected, especially Northeast Brazil but parts of Northwest Mexico, you see that actually the proportion of the total area that's inhabited by extremely poor people is much higher, and the not poor are underrepresented in these areas.

So let's take a look at some potential future vulnerabilities to climate change. And this is a dataset that I obtained from some Japanese colleagues working on the IPCC, looking at future runoff. And runoff is like precipitation minus evapotranspiration. It's used by hydrological modelers and it basically tells you where you're going to have more or less water, but it takes into account things like higher evapotranspiration as a result of temperature changes.

And so you may see higher rainfall in some regions but that could be mitigated or offset by the fact that temperatures are going to be higher. And it's somewhat similar to the map that I showed you earlier; the Mediterranean Basin, Southwest Mexico, Southern Australia.

Then if you start looking at where the people are, and this is where we're kind of about at our center, is looking at where the people are distributed globally. It's a lot of more useful to understand where people are globally when you can get down below the national level boundaries and start seeing where they are on a pixel by pixel basis. And I combined those two maps and basically looked at those people who are in areas where drought or runoff is going to decline by more than 20%.

And today, in today's population terms, we have about 400 million people or more who are in areas where drought frequency or rather runoff is projected to decline by more than 20%. So these are people who are going to need to start planting. These are countries that are going to need to start planting for the likelihood that runoff and water availability is going to decline in their areas.

Now, of course, precipitation does matter but warming will also have an impact on which areas are likely to be most suitable for agriculture. And in some areas, our temperature rises in Africa and some other region, will be above the levels that plants can really cope with during the growing season so that's going to be something they'll have to address. But meanwhile, you have areas towards the northern latitudes that you might actually increase agricultural potential.

This is some work we did on sea level rise. I was talking to Ken's class earlier this morning and we're talking about the amount of sea level rise that could arise from all of Greenland melting, and that's about seven meters of sea level rise if just Greenland melts. If the West Antarctic Ice Sheet melts, that's about five meters. So if you say 10 meters, that's way too much; 30 feet, how could you discuss 30 feet?

Well, it's not going to happen in this century but already the climate scientist, already since they released IPCC report last year, they're saying that sea level rise in this century is likely to go from what they thought was going to be about 0.8 meters at a maximum to more like potentially two meters this century 90 years from now.

So this is the Mekong Delta area totally under water, half of Ho Chi Minh City under water. This does not account for flooding from the Mekong. It does not account for storm surge that might occur. The coastal area of China, Shanghai totally under water. And then if you look at the percentage of populations globally that are in this low elevation 10-meter bands, it's about 10% of global population today, and it's about 13% of the urban population.

So that just means that there's more large cities and city urban centers than there are at this proportion on map of the world's population as urban in the coastal zone.

Then this is looking at essentially at a country level. So what we see is that some countries have very high populations in this 10-meter band; 62 million in Bangladesh, 43 million, and then the percentage of some countries, particularly small island states, is something like 88%. All these are above 50% of the population is in that band. So we're talking about some very large countries like Vietnam in terms of population that have very high percentages of the population in those bands.

We did it also for three meters, so if you don't like 10 meters, you can look at two meters, three meters. We have it for all different levels. And this shows that three-meter growth in essentially India, China--I'm going to have to zoom through a few more slides here before I wrap up so I'm going to do that quickly.

We're doing some work with CARE on climate migration and we're looking at the potentials. So this is Bangladesh with cyclonic activity in the upper left hand corner, agricultural activity. And this is just the two-meter rise here sea level.

But if you look at the Mekong, for instance, this is the flood extent in 2000, the year 2000; one of the highest floods that they had. So this conveys something. This tells you that there's more than just sea level rise we'll have to deal with. We're going to also see the confluence of sea level rise with flood events.

They are talking about living with floods in this region, and that's something that they're working on in terms of adaptation strategy. In the whole Asia region, one of the big issues is glacial melting. And these are water towers. They essentially store water in the summer months and they release the water that they accumulated during the winter months over a period. So it's like a natural water regulator.

Once these glaciers start disappearing, what you're going to have to do is essentially build human-made dams to regulate that water flow. And what you see here in dark colors is all the irrigation areas in this, for instance, in Pakistan is heavily irrigated and so they're going to be very affected by some of these things.

Very quickly, climate change impacts on health. This is a runoff map for Africa. If runoff increases, as you saw on that map, it will in some regions and the earlier map, the malaria transmission will likely increase because of the moisture in the air. You'll also see drought incidence potentially increasing as a result of climate variability.

And I've done some work to look at what some of the correlates of child malnutrition are and these are the areas that are most affected by child malnutrition. It turns out that drought frequency is one of the biggest correlates. We had looked at emerging effects as disease and looking at the human wildlife interface as well as where populations are most densely settled, and that tends to be a big predictor in terms of where future infectious diseases will occur. This is a work by one of my colleagues.

I want to touch briefly on adaptive capacity because there are a number of things that will affect how societies are impacted. And I'm not going to cover this. But one thing will be

the frequency of conflict events. And so this is just a map, an animated map, showing the frequency of conflict events in different regions of the world.

And we've looked at the relationship between water availability and droughts and their impacts on high conflict events, and high level conflict events in Africa. It turns out that there is a significant relationship between droughts in the prior five, ten-year period, and the potential for conflict to erupt in some of these countries.

Accessibility is a major factor in terms of ability to trade so much of Africa. The essential parts of Africa and parts of Asia are highly isolated. And that's an adaptive capacity element. Irrigation capacity is also something that's going to be important.

So in terms of overall conclusions, what I wanted to say is that, in general, I think the public is largely unaware of the magnitude of the challenges that we're facing with future climate change. I'm almost certain that the climate scientists--it doesn't matter if I'm certain--but the scientists who studied this are pretty much certain that we'll see a two-degree rise in temperature at a minimum in this century.

So we need to be forearmed to be able to prepare for that because these things, these impacts, these vulnerabilities, these adaptation potentials, adaptation capacity are all spatially differentiated. We can learn a lot by overlaying spatial datasets to understand these things. I have to say that a lot of dynamism, and the nuances, and the cultural elements, and the personal element are lost in this kind of analysis, so I'm fully aware of that.

It's not a panacea but it can point to where we're going to see hot spots of potential climate change vulnerability in the future. And with that I wish to thank you very much and I'll be happy to take any questions you might have.

[Applause]

Person over here.

Audience: Hi. Having to hear you being from the Netherlands long ago, I noticed the Netherlands is about the only country that's highly developed that's going to be the flood claims. Nobody started out yet at this conference what it really is going to be like when perhaps either 10%, 13%, or even 25% of the population needs to become climate refugees.

What is the world going to look like when there's no longer a Florida, when there is no longer a Bangladesh? What's going to happen? What will that world look like?

Alex De Sherbinin: Yeah, that's essentially the gist of the work that we're doing with CARE, the development NGO, and we're looking at the potential of massive displacement as a result of sea level rise, and also in this vulnerable agricultural areas that are largely dependent on rain-fed agriculture, what will happen in the future?

I mean, where Ken and I worked, there in the Mauritania, there was an arc of irrigation along the Senegal River. The rest of the country is entirely rainfall dependent. And if they see increasing drought frequency, things like that, it's going to have a major impact.

I believe there was a question down here. Ma'am?

Audience: I've heard it's said that climate change is probably the biggest threat to national security, and do you think that there's any possibility that we could ever mobilize the resources of the Department of Defense to actually start dealing with this and all of the resources, the economic resources, that go to that?

Alex De Sherbinin: Yeah. Well, a big question is whether the DOD is the real source of solution for some of these things. I was actually party to a lot of these conversations in the early 1990s when the idea of environment and security first came up and was in Washington, DC and there was a lot of discussion.

Chad Homer-Dixon, Robert Caplin and others were talking about the future which looked increasing bleak. I like what the science fiction writer, Dr. Robinson, talked about yesterday. He said Utopian's visions of the future used to be a lot more Utopian than they are today. Now, they are more survival scenarios, you know, and so that's changed as well in the science fiction realm.

But DOD may have part of the solution. We did some work for the National Intelligence Council that was looking at the sea level rise and drought and other impacts. They are certainly aware of the issue. I'm not sure they necessarily would--it's hard to tell what their role might be. But you're absolutely right. We give a lot of our money to the defense department.

Audience: I was just wondering if you had performed any studies concerning the amount of freshwater that we'll lose if these coastal areas are flooded after the ice caps melt or Greenland?

Alex De Sherbinin: Sure. That's a major issue. We haven't directly looked at that. One of the issues that you'd get--and it's very complex in the coastal zone--so what you find is that even changes on hydrostatic pressure of the sea level increase and relative to water withdrawals in land for a different purposes, you start seeing groundwater getting salinated. That's already occurring in the Ganges in that area.

Even before sea level rises taking effect, in other words, you're seeing salinization occurring in groundwater. And, you know, I think it will have a significant impact. And the reality is so the land won't be there either to farm so we'll be getting our water from somewhere else, most likely from a dammed river somewhere.

Audience: I find the map of the potential conflict areas as a result of drought and climate change to be particularly disturbing. Now, recognizing the three different coping mechanisms that you cited, what role can the United States play to ensure that other countries are able to develop these same coping mechanisms?

Alex De Sherbinin: Well, I think that's part of the reason CARE, for instance, has gotten into the climate game along with a large number of other development NGOs. And I believe interaction in a number of, sort of, consortia of development NGOs are looking very actively in this issue.

Basically, it's partly a matter of funding. It may be partly a matter of technology and expanding the rich and the availability of technologies to deal with these drought-resistant crops. In one of the tragedies of our investment in the agricultural research system, according to colleagues that worked in the CGIAR, which Rockefeller set that up to deal with the Green Revolution and to create hybrids, a lot of the research and investment went in high-yield varieties that were very resource and water intensive.

Relatively less resources have gone into research of maize, millet, Sorghum; these are crops that dry land farmers around the world depend on. And if had drought resistant variety of those, we'd be going a long way. And I think they're doing work on that now but it's not progressed along the same ways as GMOs and other things in the more intensively-cropped areas of the world.

Audience: I ran a program at Penn State on the ethical and moral dimensions of climate change and your slides are wonderful for showing that the harms and benefits are disaggregated. Are your slides available on your website? Can I get copies of your slides?

Alex De Sherbinin: Well, feel free to come down and talk to me afterwards and I can send them to you. I want to mention, those who want them, there's some CDs with datasets that I presented here. It's a data visualization tool we've developed with some colleagues, and it's actually a pretty nice sophisticated tool. I only have a few so it's first come first serve as well as some brochures of our center. Okay. It looks like that's it so thank you very much.

[Applause]