Climate Webinar – April 24, 2014

… historical trends and future forecasts. These webinars are an initiative of The Ohio State University Climate Change Outreach Team, a multi-departmental effort within the university led by Ohio Sea Grant, Office of Research, Ohio Supercomputer, OSU Extension, and eight other OSU departments to help localize the climate change issue for Ohioans and Great Lakes residents. I'm Jill Jentes Banicki from Ohio Sea Grant and Stone Laboratory, and joining me today are two NOAA meteorologists, Dr. Martin Hoerling and Barbara Mayes Boustead. Dr. Hoerling is a research meteorologist, specializing in climate dynamics at NOAA's Earth System Research Laboratory located in boulder, CO. He recently served as convening lead author for the Southwest US Assessment Report, a contribution to the upcoming National Climate Assessment, and was the lead author for the US Climate Change Science Plan Synthesis and Assessment Report. His research interests include climate variability in seasonal and centennial timescales, focusing on air speed interactions such as related to El Niño, the role of oceans in climate change, and understanding the physics of extreme weather and climate events.

Barbara Mayes Boustead is a forecast meteorologist and climate program manager at the NOAA National Weather Service office in Omaha Valley, NE. Barbara's professional and research interests include topics such as climate change, historical weather and climate events, severe and extreme weather, and improving communication on weather and climate concepts.

We're delighted to have both of them here today to talk about the weather, the recent weather events we've been seeing, and what we will see in the future. But before we get started, a few logistical issues. During our presentation all participants will be in a listen-only mode. Afterwards, I will conduct a question-and-answer session. If you would like to ask a question during the presentation, please feel free to use the 'chat' feature located on the right-hand side of your screen, and I will collect and pose your questions out to both at the end of their presentations. We have nearly 300 participants so far on this webinar, a great diverse group representing governmental agencies, academia, and non-profit groups from the Great Lakes and around the country. Please keep those questions coming throughout the presentation; we should have a great Q&A session. As a reminder this webinar is being recorded and will be posted onto our website for later viewing. Also, we will post a webinar survey in the 'chat' feature towards the end of the hour. Please take a few minutes after the webinar to fill out that survey. It will help us continue to bring you better webinars. So without any further delay, I would like to introduce Dr. Martin Hoerling, research meteorologist at NOAA's Earth System Research Laboratory who will present, 'Extreme Events in a Warming World'.

Dr. Hoerling, I think you should be unmuted, and if you want to just click on to your PowerPoint presentation on the upper portion of your screen you should be good to go.

Okay, let's see if I can find the presentation. Okay, I just did. Hopefully it's visible now to all. And welcome. Yeah, I'm going to give a bit of an overview on extreme events, and try to place them into our reality of a warming world. I'll spend a little bit of time taking us through what we understand to be an extreme event, which isn't obvious. So for instance in this past year we've had the California drought, which by some measures is extreme in a recent historical context that's maybe 40-50 years long. We've had the Great Plains drought also that occurred in 2011, mainly in Texas then it moved northward in 2012. Extreme certainly in their impacts in agriculture. We've had in our own backyard here in Colorado we've had record rainfall in northeast Colorado last September. The list can go on and on. The Missouri Basin floods that occurred in spring of 2011 were certainly extreme as far as their impacts are concerned. And then there's other features; things that we see often in the popular press. We see coverage of the carbon dioxide in the atmosphere recently being near 400 ppm. That's an extreme value. And sea ice being depleted so that by the end of Sept, this past Sept, it was near record minimum, at least in a record that extends back about a half century. So there's various manifestations of extremes, and I thought I might cover that in a little bit more detail. So let's see, if we go to the next slide here…

And it seems pretty straightforward to some of us what extreme weather is. I like to use a satellite image, it's an older picture, in this next slide just to give you a sense that there's an extreme weather event of some type or fashion that's happening in any given time in the Earth's atmosphere. This is a satellite picture with the white areas indicating bright clouds that probably have some weather related to them. You can see, for instance, off of Baja, California a swirl of clouds that is indicative of some kind of tropical cyclone in this particular image. There's a squall line moving southward moving apparently over the upper Midwest. So embedded in each of these is perhaps some extreme weather at that time. It's not unusual to see extreme weather at any given time in many places across the planet on the same day. So that's nothing unusual. So extreme weather, I guess is a point I like to make, and extreme events are not necessarily the same thing that we're talking about.

Let me go to the next slide, and give a little more illustration of that. So these are pretty common images of extreme weather that we're familiar with. There are 4 examples here. One is a southwest Phoenix example of a dust storm that's about to enter into the town; sort of an extreme event. The tornado image, well we call that an extreme weather condition if you're in tornado alley it's something that you expect, so it may not be an extreme event in any particular fashion. Of course if you get hit by a tornado it definitely will produce an extreme impact. The flood picture down in the lower left is similar. Heavy rains are not uncommon. In some parts of the country, rains that are heavy have a seasonal dependency; California in the winter time, and so forth. Landfalling hurricanes and so forth produce heavy rain. Those are again are extreme weather, but they're not necessarily unusual events or the like. Heat waves have become more frequent. Heat waves themselves are not necessarily unusual, but they are becoming more frequent, and so there's an example of something that might be changing as an extreme weather phenomenon in a warming world.

I want to mention again the tornado example. A tornado itself is not an extreme event necessarily, especially in tornado alley. It might be if it happened in California, especially a strong tornado would be very unexpected there. But in this current tornado season, so we're now almost at the end of April, right now the estimates from the National Severe Storms Laboratory in Norman, Oklahoma is that we're perhaps experiencing the lowest, the slowest start to any tornado season since 1953 or so. That would be an extreme event, that is to say how rare, how few strong tornados have occurred so far this tornado season over the US. And these things can change quickly from one year to the next. For instance in 2011, we had a very fast start to the season. It was one of the fastest starts on record. So far this year we've had about 20 strong tornados, F1 or greater, whereas in 2011 at this time we'd had about 465. So what seems to be an extreme event can also show a lot of variability from one year to the next. Let me go one to the next slide and be a little bit more specific about what an 'extreme event' is.

And so I use the example of the tornado count as one example. I'm going to come back to that as a theme in a little bit. NOAA has a broad definition of an 'extreme event'. NOAA is assembling a factsheet, which unfortunately wasn't quite yet ready for our webinar today, but will be available quite shortly. It's a two-page sheet that lays out some of the understanding about extreme events and how they're changing. And I'll cover some of the points of that factsheet in the presentation here today. And this definition which is also the definition used in that factsheet is that an 'extreme event' is a 'phenomenon that is rare from a meteorological perspective'. So rare might mean might something that happens once every 50 years, it's somewhat arbitrary what we mean by rare, I'll come back to that in a second also. It's certainly not something you'd expect to happen every year, maybe even every decade; that's not particularly rare.

Or the event could have a high impact. So this may not be necessarily an unusual meteorological event for a given region, but when it happens it can produce a significant effect on society. So a couple of examples to sort of illustrate. The Joplin, MO tornado in 2011 certainly was a, it was rare in terms of its severity, its duration on the ground, and it had a high impact. It basically covers both of these broad definitions. Almost exactly three years ago to this week there was a very unusual, I'll say a rare, an extreme event, tornado outbreak that occurred in the eastern, southeastern US. There were about 358 tornados during the week, the last week of April three years ago. 324 fatalities, so the impact obviously was very dire. But sometimes a high impact occurs without necessarily having a rare meteorological event or single event. The Missouri flooding case of 2011 would be one of those examples. A sequence of unusual, but not necessarily rare events sort of conspired to cumulatively lead to very high flooding. There was snowpack in the mountain in the upper Missouri basin that winter, it was a cold spring, the snow didn't melt on the plains, and then late spring some heavy rains occurred, and they combined to produce a sudden melt of all of that snow that was in storage on the ground and on the mountain. And then with the rains, and then extreme flooding then occurred on the river. So the impact was high. The cumulative effect of these different factors led to an unusual meteorological event that itself may not have been necessarily rare.

So let me illustrate this a little further with a schematic. I'm sure many of you have seen this type of simple curve, but I still want to spend a little bit of time on it because even I get confused sometimes about what these curves are actually telling us or trying to tell us. So I'm trying to illustrate in these bell-shaped curves the notion of what we mean by an 'extreme event' or an 'extreme value'. It says right there an extreme value or extreme event can be thought of as being the smallest or the largest value in a sample of observations. And so in the dark green curve, for instance, is plotted a frequency distribution of some meteorological variable, think of it as temperature for a given day or monthly average temperature, over which we have a long record of such measurement. And many meteorological variables when you plot them in terms of their frequency distribution plot out in to a bell-shaped curve, like this green curve is indicating. And when looking at that curve the middle of it, the peak value would be what we would typically call in climatology the normal value, the expected value for that variable in that region. So that would be the normal condition, if you will, the average or most frequent occurrence might be the normal. And then there's a range of possibilities that occur from time to time that deviate from that normal. About ⅔ of the samples of, let's say daily temperature, can deviate by what is indicated as a – 1 standardized departure and +1 standardized departure. There's two vertical lines there. That range consumes about ⅔ of all of your samples. So all those numbers wouldn't be considered extreme values per se, but by about the time you get to two standardized departures. On the x axis they're plotted out as -2σ out to +2σ, those values are less frequent. They happen maybe once 50 years, about 2% of the samples in your data. If you have 100 years of data, 2% of samples would mean you would expect once every 50 years you'd have two standardized departures. As opposed to the one standardized departures, a pretty frequent event. It would occur about once every seven years; 16% of the time. And then the less frequent one yet, the three standardized departures, is something you wouldn't necessarily expect to experience in your lifetime. This might be like a 1 in 500 year or so event. It might be even difficult what that value truly is if you only have 100 years of data.

Now the thing that we're really concerned about is how that distribution, that dark green curve, changes in a warming world. So schematically there's a light curve that is plotted on top of it which has been shifted to the right. If this was temperature it'd be the warm side of the distribution. So the way that shift was graphed was to give you an idea of the magnitude of these things. Roughly the shift is about equal to one standard deviation of the original distribution of the data. And so what that means now is in this new climate as indicated by that light green curve, the condition that would be a one standardized departure relative to the new climate would be equal to what used to be a two standardized departure relative to the old climate. Or another way of thinking about that, an event that used to be pretty rare, once every 50 years in the old, cooler climate if this was temperature, becomes something that is pretty common, comes once every seven years in a warmer climate. And in some places in the US climate has warmed to this extent, the southwest US would be one region in particular where the shift in the temperature distribution is roughly on the order of one standardized departure of the long historical record.

So why is it important to understand extremes and their change? I think the best way to answer that question is, there's sort of many ways we could answer that question. The way I like to look at it is in terms of the impacts, and billion dollar event impacts is a useful way for us to look at that. And NOAA compiles, in the next slide I just brought up, NOAA compiles the statistics of billion dollar weather or climate disasters. And it has been doing that at least since 1980, and in this six-paneled picture is a summary of about, let's see we have 32 years' worth of statistics of various meteorological hazards, and where they have tended to produce billion dollar events. The colors are indicating the of number of such events. The darker the color, the greater the number of such events that have occurred in the period of record. And one, couple of things that stand out in this analysis is that there's definitely a geographical preference. This wouldn't surprise many of us, of course. There's a geographical preference for the impacts of various weather events. So for instance, not surprisingly hurricanes and tropical storms are of greatest impact in the eastern seaboard and the Gulf of Mexico, and not so much in the interior of the US. Although, some of that gets sort of little bit confused because remnants of tropical storms do produce flooding. So if you look at the lower left panel you'll notice a high frequency of flooding, which occurs in the part of the Ohio Valley, the Mississippi River Valley, Texas. Some of those are remnants are tropical storms, some of them are river floods from water that comes down the Missouri or Mississippi river systems from rains that fall within the basin as a whole.

The flooding one is also an interesting one. It sort of reminds us about how we can fool ourselves into thinking that extremes are not likely to happen in a given area based on a dataset that is actually pretty short. 32 years of data is a lot of data for most of us because we move around, we're a mobile society. We're not usually, we don't usually live in one place for more than 30 years at a time, so we may lose track of the likelihood of extreme weather in our own backyard. But you'll notice in the flooding picture that there's a north-south gap of flooding. There hasn't been any flooding events causing billion dollar damages in New Mexico, Colorado, and Wyoming, at least for data through 2011. Now someone might say 'well that's great, I'm going to move to a place where I don't have to worry about flooding'. So someone may've moved from Illinois or Iowa and said 'I'm done with flooding, I'm going to move to Colorado where it never floods', and lo and behold last year we had one of the worst floods in our record. And so again it reminds us that 30 years of data may not be a very definitive assessment of the exposure to these types of extreme events.

Another thing that's interesting in this picture is that the impacts here… it shows the complexity of this interplay between an extreme event, its frequency, and how it effects a region. So for example, winter storms and cold freezes. Well, we sure know that for those of us that live or have lived in the Dakotas that winter storms can be vicious, and frequent. This winter would be a great example. And so what's up with that? Why are there no damages related to that? And I think that has to do with the exposure. Societies do become, people do become, cities, communities acclimated, if you will. They become resilient to, adapted to particular types of events in their area. They take measures to protect against such events. Or the exposure. So crops are not as abundant in that time of year that are exposed. On the other hand, premature cold events that move into the southeast can cause citrus crop damages and so forth. So the picture is really has many layers. It's quite a complicated story when talking about extreme events and their impacts in their entirety. It does require quite a lot of consideration.

So let me go to the next slide. I'll just briefly mention that the interplay between a climate event and the vulnerability is really what matters in terms of figuring out the disaster risk that we're concerned about when talking about extreme events. So I guess they're certain perpetual questions that we're always dealing with. For example, is the frequency of an extreme event, let's say a tornado season being active or hurricane season being active, are those statistics changing? And at the same time we wonder is our vulnerability to that changing? And related to that are we more exposed to these events than we were at a previous time? These almost sound like an actuary questions that an insurance firm would ask of themselves. But these are questions that kind of lurk in the back of anyone's mind when they move to a certain area or place roots in a particular area, make a decision to get a beachfront property in a certain area. So one way that's sort of interesting to think about this is a person that would be living on the third floor in an apartment may not be especially vulnerable to flooding. But they would increase that vulnerability quite a bit if they moved into a ranch house. And they would increase their exposure if they bought that ranch house on beachfront property in so far as sea level has been rising and at a beachfront property in a ranch house you're more prone than let's say 60 years ago to experience a flooding event. And so in this sense, a disaster risk, that middle white area, would be substantially increased for a person or family that moved themselves from a third floor apartment dwelling to a ranch house on a beach. Both because there's been an increased risk of flooding in coastal zones because of rising sea level, not necessarily because storms have been increasing. The evidence for that is not strong at all. But the evidence for sea level rise is very strong. And they've increased their vulnerability because of the way now that they're living, choosing to live in a ranch home on the coast. So you can make different scenarios to tease that out, that vulnerability out.

So how do we know if extremes are changing? And it's worth going back and thinking about what does the average person know about weather in general, again the mobile society dilemma. Most of us are not aware of the full range of extremes that can happen in the area that we live in mainly because we haven't experienced the full range of that area for an extended period of time. Even if we do have backyard weather stations most of us probably don't have records for that weather at our backyard that is much more than a few years in duration. So basically our awareness of weather and climate, and how it may be changing, at best may be on the order of years to a decade in duration. But really scientists and the data that scientists collect are really important in giving us this long historical perspective. Not just with instrumental data, which in some places might be 100 years in duration, but paleoclimate data, which reconstructs or estimates from reconstructions using proxies of thermometers let's say for temperature or proxies of rain gauges for precipitation, so tree rings for instance, what the climate of that region might have been for hundreds of hundreds of years. So these are important datasets that allow us to monitor how statistics have been changing over a long period of time. And in addition to these there are also models that come into play. Models of the earth system that are sophisticated and complete, but they certainly also suffer from some biases, but they're essential tools to look at the plausibility that climate change in a warming world could be effecting some type of weather event in our area.

So just to give a short and a link here. NOAA, for instance, does archive of the nation's climate data. The National Climate Data Center has the types of data I just mentioned to you. There's a link you can get to for information specifically about extremes. Paleodata is also part of the data archive, and these are valuable legacy datasets that tell us about our history of climate and where it's moving at this time.

Pardon me.

So I thought what I'd do here is from these datasets, I'll give you a few examples of extreme values in our climate record that are beyond any doubt. That there's no question for instance that the carbon dioxide concentration of the atmosphere each year is itself an extreme event, or if you will acquiring an extreme value. This is the time series that the global carbon dioxide concentration estimated since year 1000. These records which again are partly paleoreconstruction, in the period since about 1950s it's from measurements. But you can see that the uptake has been a phenomena of the industrial revolution. The carbon dioxide concentration when I was born was about 310 ppm; now you know how old I am. And we've been actually hitting values close to 400 ppm in the last year. This time series is a little bit dated, so we are now higher on that curve at the 400 ppm level; an extreme event on an annual basis.

Another example of an extreme event is in the amount of energy that is being accumulated in the oceans of the world. Two-thirds of our planet are covered by water, and these oceans act as a reservoir for the heat that is being trapped because of the increasing carbon dioxide and other gases in the atmosphere. And this bathtub is warming, and also because it's warming it expands, and that's back to our story about the coastal inundation and sea level rise. And this is a time series from 19… let's see I believe it's 1970. It tends to measure the amount of energy, heat contained, within different parts of our Earth system. The blue, light blue, is the upper ocean. The dark blue is the deep ocean. And then there's the land at the very bottom, and the atmosphere. You'll notice that the atmosphere is a very small reservoir for heat. Most of the energy that's accumulating is accumulating in the ocean. Some of it goes deep down, some of it is right there at the sea surface, and it's that energy at the sea surface that finds its way back to the atmosphere and is warming surface temperatures in our backyard.

The oceans are becoming more acidic. Again, this dovetails back to the carbon dioxide. This time series is 1950 to 2010, and into the future these are model predictions or projections. But the oceans have become more acidic, and these are extreme values based on historical. Even though they are small changes, they are important changes and their extreme in their values.

And on that you might be more familiar with that you've seen in the popular press, if not in the science literature is that the temperature of the planet has been rising. Again, paleo-reconstructions tell us something about the last 1000 years; thermometers tell us in more detail what's been happening the last 150 or so years. And this curve is sometimes called the hockey stick because of the rapid rise in the last 150-some odd years in the temperature. Almost on an annual basis, but certainly on a ten-year average basis the planet is achieving new high record values on an ongoing basis. There are wiggles as you can see from year to year. There are some periods that don't warm as rapidly. A hiatus sometimes occurs like we've been experiencing the last 15 years, but the trend is demonstrably upwards and extreme values are the norm in the global temperature.

Sea ice. Well, sea ice has been going down. It's been going down strongly in the last 15-20 years. The image you see here is a satellite, a NASA-based satellite image after removing the effects of clouds, there's an outline that shows the typical sea ice extent at the end of September. And then you can see white where the actual sea ice concentrations were, I believe this was a year, maybe two years ago, I can't remember exactly. But the sea ice has reduced its extent by a substantial amount, and that does effect the climate, and it goes through the Arctic in particular.

So, how do we determine the effects of humans on these extremes or on extreme weather in particular? And one way that we do this is using climate model simulations. And I thought maybe I'd just focus on that just real briefly to give you a flavor of how climate modelers go about this exercise. And here you see two panels, let me talk about the first one. These are time series from 1900 up to about 20.., looks like 2005 or 2010 actually, of the globally averaged temperature, so the temperature of the planet. The black line is the observational record, and then there is a red line which cuts through that, and that is the average of a multitude of climate models that are used in many different institutions around the world as part of the Intergovernmental Panel on Climate Change assessment of how our planet is changing in response to greenhouse gas forcing. These models have been given the information of the CO_2 time series I showed you amongst some other information, such as methane, sulfate aerosols, volcanic and solar variability, and when that information is put into the climate model you can see that they produce a time series of the observed warming, including some of the pauses in that in the 1940s quite faithfully. And there's a band on that, that's the yellow that shows all of the separate models. And you can see there's some uncertainty at the rate of warming at different times, but the overall upward trend is clearly indicated here to be due to the response of the Earth system to the change in greenhouse gas changes. To make that point stronger the climate modeling centers also produce a parallel experiment in which they withhold the change in carbon dioxide, and only let the climate models that they run react to the changing volcanoes, which indicated by name in the vertical bars, and the changing solar cycle, the solar variability if you will, and that's in the lower one; the blue curves. And you can see that they fairly match the observed record up until 1960, and then the two, the observed and the naturally forced experiment as they're often called, diverge. And so that gives us that strong basis to argue and the evidence for the claim that most of the warming of the global averaged temperature in the last 50 years is due to human influences through the greenhouse gas effects.

So are extremes changing over time, and if so why? I won't be able to go into that in a great detail. There's a table here, which I'll show you in a second. But I'll give you highlights from the latest Working Group 1 report of the Intergovernmental Panel on Climate Change, and what they call out is some of the most robust changes in extremes that have occurred to date. Now I'll just read this with you. "Overall, the most robust global changes in climate extremes are seen in measures of daily temperature…" So basically all boats are rising with the tide. The planet is warming, and daily temperatures in many areas are rising with that tide. And including to some extent, heat waves, which are becoming more intense or more frequent. Precipitation extremes also appear to be increasing. That evidence is strong, but not as strong as for temperature. In part this is consistent with the fact that the warmer climate holds more water vapor, and therefore precipitation, when it falls, tends to be more extreme in many areas; not all areas. Again it says there's large spatial variability and mentions that 'there's limited evidence of changes in extremes associate with other climate variables". So for instance these would be hurricanes, tornadoes, severe thunderstorms, extra-tropical cyclones, strong storms in the wintertime. The evidence for changes in those are not very compelling, and so the variability that typically occurs still continues to dominate from year-to-year, even decade-to-decade.

This table is meant for your reference just so you know that there is a systematic attempt to look at a whole host of extremes. The table has four columns that speak to in the first column what has been the observed evidence for changes, the second column speaks to how much do we believe the human influence is due to those, and then the third and the fourth talk about the likelihood that climate change going forward for the next couple of decades and then toward the end of the 21st century will effect various extremes. This is in the report from the IPCC, for which you'll have a reference at the end of this presentation.

Can individual events be attributed to climate change? So we're kind of getting toward the end of it. The short answer is yes, they actually can. In fact, this may seem like a trite statement, and in some ways it is. Human induced climate change effects all weather events. So that doesn't tell us very much because it doesn't tell us by how much these events are being effected or in which direction. But the fact that the weather events that are happening they are happening in a different climate, and they behave in some fashion or form differently than they might have behaved a 100 years ago. The question is by how much. And that's the key science question. This is one of the permanent questions that we have, for which right now there probably aren't any permanent answers. There's an evolving science on that. It does gain significant visibility in policy, so for instance this is a cartoon version of the president's State of the Union address in February where he called out the importance for the nation of extreme events whether they were changing. I'll just read it with you. 'We can choose to believe that Superstorm Sandy [which had a significant impact of course] and the most severe droughts in decades [that was the Great Plains drought] and the worst wildfires [that was in the west] were all just a freak occurrence, or we can choose to believe in the overwhelming judgment of science.' So the question is what does science tell us about these events? As I mentioned hurricanes and so forth have not necessarily changed due to climate change, but the sea level is higher. And when these storms bring landfall they bring higher sea levels and coastal inundation results. So that impact is very distinct and occurring, and will likely grow in its impact over time.

There's a question about events becoming more frequent, or events, when they happen, being more intense. These are sort of two of the science challenges that we have when talking about climate change. So did the climate change effect the likelihood of an event? In other words, a heat wave that used to be once in every 50 years may be now once every 10 years. How about a rain event, a very heavy rain event like happened in Colorado. This is part of the science that needs to be done, often on a case-by-case basis to quantify these things.

Annually now there's a report in the Bulletin of the American Meteorological Society (AMS) that pulls out the previous year's events that were extreme across the globe, and it tends to explain these in a scientific manner, and in a timely manner so that the report comes out in Sept, and it reports on events that happened the previous calendar year. So right now for instance I'm co-editor on this publication from the AMS. They're about 25 events that are under review that are being studied. The report will be peer-reviewed, and it will be published again by Sept, this Sept, and you'll be able to learn about events like the Colorado flood, the drought in California, and so forth. What the current science has to say about that. Trying to be timely and informative.

Here's just a list of references for which you can follow up on some of the items certainly skipped over very quickly, but hopefully it whetted your appetite for today. And I think that was my last slide. Thank you, thank you so much for listening in.

Thanks, Marty. We've gotten some really great questions. We will wait until after Barbara presents to get those questions answered. So I would like to introduce Barbara Mayes Boustead, forecast meteorologist at the NOAA National Weather Service who will present 'Climate Connections and

Predictions to Weather'. Barbara, I think you are unmuted, and you should and you have the ball, so you are ready to go!

Okay. Thank you, Jill, and thank you to Marty for a great presentation to lead into mine. And thanks to all of you who are listening. I'm going to start by giving just a bit of an analogy. We've talked a lot about weather and climate, and sometimes it's a little tough to make the distinction between the two. So there are some analogies out there, not only for the benefit of you who are listening, but maybe for the benefit for you to carry on to give to other folks who might be both interested in weather and climate. You know weather is the short term stuff that happens, and climate happens over a longer term, but that can be really hard for people to visualize. So some of the analogies include the climate is the clothes in your closet, and the weather is the outfit you choose for a day. Climate can be your personality, and weather is your mood. Or my favorite because we're getting into baseball season, climate is like a batting average and weather is an individual at-bat. And so we're going to talk about how that batting average can influence an at-bat, but doesn't necessarily dictate an at-bat.

There are a number of players in our climate system that can influence the kind of weather patterns that set up. One that we're going to talk about quite a bit a little bit later is El Niño and La Niña. We also see the Atlantic Oscillation and North Atlantic Oscillation. We have influences from the Madden-Julian Oscillation, and simple blocking patterns as well that can influence what's going on. And finally as Marty just alluded to a couple of minutes ago, climate trends are basically the background of all weather patterns that are happening now. So how do all of these come together and influence our weather patterns?

Well, they layer on top of each other. They can sometimes outweigh one or another, and they all can have an influence on weather, so it makes a kind of muddy and complicated pattern, which is why we can very rarely say that a weather or climate extreme event is attributable to just one phenomenon, is just because of El Niño, for example, or just because of climate change. Because there's so many of these factors that layer together and tip the odds in one direction or another.

So I'm going to actually talk about tilting the odds here for just a minute, too. In the absence of any influencing patterns, we basically would have a pretty random equal shot at getting in any category of an event, and this could be temperature, precipitation, chances of hurricanes, or whatever climate event is of interest you're considering or weather event of interest. In an average distribution we have an equal shot of getting any of these categories, near normal, below normal, or above normal. What we do when we set up climate patterns is tilt the odds. So for example we might tilt the odds toward the below normal category, just by shifting that distribution a little bit. Or similarly we might tilt the odds towards an above normal category of something happening just by a small shift in the probability. And I'm really glad Marty took so much time to set up these diagrams because I can talk a little bit more about them in a different way, so thank you Marty for doing that. Marty showed you the one on the upper right corner, letter 'b'. How an increase in the probability can shift the extremes. So if we take our usual temperature distribution now and we shift it to a warmer climate, we would shift it towards more of those extreme events and in a lot of climate applications we talk about shifts in the odds of an average. So you hear about the average temperature rising due to climate change or you hear about maybe El Niño influences the average precipitation you might get in your area in a winter. But it's more than just the averages that change; it's the whole distribution, which means it's the chances for those extremes also change, and that's true for both temperatures and precipitation. And we can get even more complicated as some events not only move the curve left or right, but also change the shape of it and can change our potential to get extremes.

So I'm going to focus a little bit more on the nearer term for now. We'll talk a little bit about climate change, too, but I want to talk about climate forecasting and how we connect these climate patterns to the potential for weather events. And one way we do that is in our climate models. There are weather models for example that we use to make our daily weather forecasts of what the temperature is going to be, what our chance of precipitation is. Climate is a lot like that, too, and we use these models, put them together, look at some different ones that are out there so that we can come up with our best estimate of an answer. But there are some differences with climate model interpretation and weather model interpretation. One of these is that in a weather forecast we're getting pretty specific, you know? For example, we're going to tell you we're forecasting a high of 72, and it's going to rain between 3 and 6 pm, with a chance for thunderstorms. Now in climate forecasting we don't forecast that specific of information. We forecast chances, or even more accurately, we forecast a change in the chances. So for example, I'm showing you the Climate Prediction Center's 6-10 and 8-14 day outlook, and we're predicting the chance for the temperature and precipitation to fall into the categories of above normal, near normal, and below normal. So a 40% outlook from the Climate Prediction Center means that there's a 40-50% chance of that category happening instead of the 33% chance we would expect from just randomness.

We also see these outlooks at the one month and three month scale, so again we're just forecasting the chances for a shift in the odds. If you look at the map, especially the lower left, May, June, July 2014 temperature outlook, areas that are brighter in color will catch your eye. So let's focus a little bit on California just as an example. The color shading is a little darker in California with a 50% contour there, which tells us there's a 50-60% of temperatures to be in the warmest third of the climatology of California. And, you know, it's important to remember that shift in probability does mean that the other categories are still possible, and it doesn't how much above normal the temperature may be, just that it would fall into that category.

Getting a little closer to extreme events, we also look at outlooks of drought. Both at one month and three month scales. Now drought is an extreme event. There are some parts of our country that are prone to drought occasionally, and having drought is sort of a normal part of their climatology. But how long it lasts and how bad it is can make it an extreme event. And a good example of that is the southwest United States, where it is already a dry climate and having some dry periods is expected. But when those periods last longer than normal or are more intense than usual, that's when it becomes an extreme event for that location. And again we can predict the chances of coming out of drought or going into drought based on signals that I've showed you earlier, things like trends or influences like El Niño, La Niña, and others.

But let's get back to talking about climate change for just a minute because as Marty showed you climate change can discuss both what we've already observed and what is forecast to observe in the climate sense. So there is already evidence that temperatures are increasing, and Marty showed the hockey stick graphic, just a little bit shorter in duration from 1895 through 115 years, so through 2010. And this is just for the Midwest region of the United States. Precipitation is also increasing around the area, at least in the Midwest US. Some other parts are seeing decreasing precipitation trends, and some areas don't have a lot of trend, but maybe their variability in precipitation is changing.

Well much like we make our seasonal climate outlook, we also make these climate forecasts or climate projections into the future. And again we're not predicting the actual temperature in these future decades as much as we are predicting the potential to shift the probability and shift the distribution. These are graphics taken from a draft national climate assessment again for the Midwest region, and they show that the potential for temperature increases in our warming climate, 2041-2070 with two scenarios being presented out there. The one I'm showing is the worst of the two if you will, the more extreme of the two, which is to have little or no change to our emissions, basically sort of a business as usual scenario if you've heard it that way before. This shows sort of the most that could be out there, and it's sort of a high end outlook from the study, but at the same time depending on the politics of what happens with emissions it may be the most likely one as well. Well temperature changes in the future indicate that we are trending toward nighttime warmer faster than daytime, and we're trending toward winter warming faster than summer. These kinds of influences and trends show up in our seasonal climate outlooks, but they also show up in our future projections and of what kind of extremes we forecast in the future. So for example one thing we've learned is that hot air outbreaks, or heat outbreaks, are really bad not just when the daytime temperatures are really hot and the humidity is high, but when the nighttime temperatures stay hot and humid because that's when a building can't cool off or people don't have air conditioning can't cool off, and they struggle more to deal with the heat. A projection of warmer nights in the summer in the future indicates that that kind of a heat scenario could be more frequent in the future. We also might see a longer frost-free season in the future with these temperature changes in extremes.

Precipitation is harder to forecast whether you're talking about weather or climate. Whether I'm talking about the rain possibility this weekend, or the potential for precipitation to go into an above or below normal category this summer, all the way through our climate change scenario well into the future, decades into the future. It's always just a little less certain because precipitation is just a little more difficult to forecast. But from the trends that we can see, the precipitation changes also like temperature depend on time of year, and in the Midwest springtime precipitation is increasing more than other parts of the season. It may be that we see both longer droughts and more heavy rain, which is a little hard to kind of wrap your head around and think about, but it's possible to happen when you have a warmer environment drawing more moisture out of the ground and putting it into the air, but also that warmer environment making it more difficult for precipitation to form and fall in those areas. What that means is we're trending more towards of the extremes on both ends on both places, both drought and floods or heavy rainfall. At least in the Midwest it looks like the changes in extremes do tilt towards more frequent heavy rainfall and higher heavy rainfall totals, so at least in this region the potential in the future is towards those extremes.

And if the changes in extremes have a number of influences, and I'm going to show just a few examples here. They can certainly effect our human health as I mentioned with the heat problem. They can affect the potential for extreme events to occur. But they can also influence crops, which in this part of the country is really important. And there've been studies that show that corn and soybeans both have lower yields with hotter temperatures. You might've heard some folks saying from time to time that more carbon dioxide in the air is good for plants, and to an extent that might be true, but the influence of higher temperatures outweighs that potential in the future. So the potential to bake the crops and make them not grow as well is a little bit higher than the potential for any increase in carbon dioxide to make the plants grow better. And it's true that seed technology will change in the future, and maybe the crops won't be quite as sensitive to the heat, but right now they certainly are. And they're especially sensitive during certain times of the crop season.

I wanted to come back around now to talking about El Niño. And the reason I wanted to is because you all might have heard of tornado watches and severe thunderstorm watches, maybe winterstorm watches. We are under an El Niño watch right now, meaning that the potential for an El Niño to develop is increasing for this coming summer and fall into the winter. So I want to talk a bit about how El Niño specifically can influence our potential for extreme weather, in the Midwest, too, but also around the country. So in an El Niño we tend to see a stronger than usual jet stream really kind of screaming across the southern United States. And where that sets up can be a little different with every El Niño episode; it's not always exactly right here, sometimes it's a little further north, sometimes it's a little further south. But the potential for that jet stream, increased jet stream somewhere across the southern United States certainly increases. And then what that tends to do is make the southern US especially in the winter tend toward being a little cooler than normal and a little wetter than normal as they're kind of getting a lot of storms coming through. Meanwhile up to the north, that area is kind of left high and dry. They're removed from the storm track, so the tendency in an El Niño year is for the northern plains and northern Rockies to tend to tilt the odds towards being warmer than usual, again not something that happens every single time. It depends on what else is going on in the atmosphere, but at least part of the time or at least more often than not it happens in this part of the country. And also parts of this area tend to be a little drier than usual as well. Again because they're not getting the storm systems that they usually get carried in on the jet stream.

So we tend to see an El Niño happen because of unusually warm water in the Pacific Ocean near the Equator. That changes where thunderstorms happen over the Pacific Ocean, which drives the jet stream across the southern United States. And one other factor that can happen in an El Niño is an increase of wind shear over the Atlantic Ocean that tends to create decreased hurricane activity.

Now with our El Niño watch in place we're watching for the potential for this El Niño to develop this summer. What I'm showing on the right here are temperatures, actually ocean temperatures below the surface. If you picture this top line of each graph as the ocean surface, and as you go down in the graph we go further down into the ocean. That pool of warm water just beneath the surface has been increasing in intensity and increasing in size as it pushes a little bit eastward through the last few weeks. So this pool being pushed eastward on some wave action going on in the Pacific is driving that potential for an El Niño, and at least according to some experts it's a fairly strong pool of warm air, warm water, excuse me, and has the potential to create a fairly significant, let's say moderate to strong El Niño event if it develops as we expect. And we're starting to see some of these sea surface temperature anomalies break to the surface, so out here in the central Pacific, right about at the dateline, we're starting to see those warm temperatures really get going out there. The climate models that we have are almost unanimous in developing this El Niño by late spring or early summer, some of them a little later , maybe summer into early fall, and they're also getting pretty good agreement in developing this sort of not just an El Niño but maybe a moderate to strong intensity event. Well the more intense an El Niño event is, the more confident we can be about it creating an atmospheric response that we can see in our weather events that happen through the winter.

And this last example I'm going to show you is just one tool that we have in the National Weather Service and in NOAA to analyze the impact of both trends and info. What we're looking at are two graphs, both of them for Cleveland, as the Jan, Feb, March minimum temperature potential. And the first thing you'll see on the left is that there is a trend towards an increase in extreme minimum temperatures. So by and large it's harder to get extremely cold temperatures in Cleveland during the winter, not that it doesn't ever happen, but it does get harder to do. And then we can look on the right here and see that in an El Niño versus neutral and La Niña it skews our probability towards getting certain conditions. So focusing on the right-hand side of this graph with El Niño, there is a significantly higher than usual potential for those extreme temperatures to stay on the warm side through Jan, Feb, Mar in Cleveland. What does that mean? It's even harder to get minimum temperatures to go into those really cold extremes in an El Niño in Cleveland. We can do this at sites around the country. We, literally thousands of sites we can analyze, and if you're interested in analyzing those I'd encourage you to sign up for an account if you feel comfortable, or get in touch with your local NWS offices if you're less comfortable working in the data yourself, and we'd be happy to talk about the interpretation because as we go into this winter we are keeping an eye on this pattern in particular and how it will influence.

But one good example to end with here before I wrap up is just a few years ago. The winter of 2009-10 was also an El Niño winter, not quite as strong of an El Niño. But there was another climate signal that was out there, too, and that was the North Atlantic Oscillation, NAO. And NAO went strongly negative throughout that winter, which tends to bring cold air to the central and eastern United States, and at least in that winter the NAO influence dominated over the El Niño influence, and so the fingerprint of El Niño was much harder to see through the course of that winter because of the influence of other signals. That kind of layering or overlapping of influences can happen just about any year and with just about any event, so this is why we talk about changes in the odds as opposed to real confident and direct forecasts. Because even at Cleveland here you can see that it's a lot more common to get those minimum temperatures into the warmer category in an El Niño, but it still happens that they can happen into the below normal category as well.

And like Marty I've included some links and resources here, just some weather and climate information. Certainly, if you have any questions I hope we'll hear them on this call, or you can get in touch through your local offices as well. And thank you again for listening.

Thanks Barb! We have gotten a lot of great questions, so let me just see if I can get both Barb and Marty both on. I'm going to try to do where, start with Marty's, the Marty questions, and then to Barb, yours. But there may be ones where each one of you may want chime in with the other. So I wanted to make sure both of you were unmuted. Okay, these questions, we've gotten a lot of questions about specific events in the past. And so I'm assuming this is probably more Marty because they were during your presentation. First question that we got was why has the hurricane activity seemingly been on the decline since Katrina?

That's a really good question. So hurricane activity varies a lot on the 10 year, 15 year, 20 year timescale. The records, which were not very precise before the satellite era because satellites really help us pinpoint the occurrences of hurricanes in areas that aren't well observed otherwise. But suggest that there can be large differences from one decade to the next, one year to the next. That's just the nature of the hurricane behavior. It's extremely variable, so the caller is correct. Since Katrina there have been much less landfalling hurricanes in the US mainland in particular. The number of Atlantic storms has generally been low. But especially the number of landfalling storms has been very low. I wouldn't read anything into that besides these variations come and go. Barbara made the excellent point that with an El Niño developing this year, the Atlantic hurricane frequency is more likely than not to be lower than normal. It doesn't mean that one storm or two storms can't find their way and do significant coastal damage, but again with the conditions unfolding toward an El Niño this year, we would expect another year of less than normal Atlantic hurricane activity. In terms of climate change, the indications from the climate change modeling community, which is a challenge because hurricanes are difficult to represent in these climate models with all of their necessary details and complexity. But what information does exist suggests actually that the frequency of Atlantic hurricanes might actually go down slightly, but that the odds of a very intense hurricane, these category 4 or 5 storms would increase. So that makes for a very mixed picture because most of the damage happens with those rare events.

Marty another question that, and I'm sorry, Barbara, did you have any additional information? Sorry I didn't mean…

I think Marty answered that really well.

Okay, great! Another question, Marty, that we had gotten was one person wanted to see if you could elaborate on your statement a little more about the 2011 flood not being an extreme event? They mentioned the fact that with the runoff, per the corps of engineers, was at 246% above normal and the highest amount in the 114 years on record. They were just wanting to see why you said that.

Right. The flood was an extreme; in terms of the hydrology, measuring the stream flow at Sioux City, Iowa for the flow that comes down the Missouri that comes into the upper basin. So the flooding event as a hydrologic was extreme; record breaking, and I think the record goes back until about 1900 or so;

early 1900s. But what was not so extreme by comparison is any single meteorological condition. It was a sequence of meteorological conditions that it came into, came to bear that cumulatively ended up favoring such a large hydrologic event. And so this is just, it was meant to give a bit of a nuance that an extreme event may occur, sort of the straw that breaks the camel's back syndrome. A sequence of mediocre or moderate situations evolve, but they evolve in sequence or in tandem that collectively do break the camel's back. In this case the camel was the flood in the river, so that's why I said why I did. But I appreciate the clarification. So yes the hydrologic event was record breaking.

Okay, thanks, Marty. Another question that we got and this probably can be to either of you or both of you. We're getting a lot of these questions, and you can just insert whatever state. What can we expect as Ohioans as far as extreme storms in the next 20 years? Are the increased winds we've experienced recently attributed from climate change? This is a question that we have gotten actually quite a few different states asking the same thing.

Hey, Barbara, you want to start on that one?

Sure, I'll start on that one.

You do 49 states, and I'll do 1.

Haha, thanks, Marty. I'll give you Colorado, too.

You know, there are varying impacts across different states. For the next 20 or so years, though, the influence of climate change trends will be really tough to pick apart away from the other variability that we see. So for example, the influences of El Niño and La Niña, or the North Atlantic Oscillation. Climate change is happening as a subtle background, and it will really be sort of mid to late century when it becomes a lot easier that there really is quite a bit of difference from the state we're in now. But we are seeing those impacts already, of course. And if you're really curious about what your own state is seeing or what's happening for you, I would actually point you to, I'm going to try to use this pointer graphic, that particular link right there; the National Climate Assessment. It's a draft form right now, but it will be out in its final form shortly if it didn't slip by me already. And it's broken down by region of the country, and each region gets their own chapter that talks about the influences that are expected through the next let's say couple of years to couple of decades. I would encourage you to head in that direction. But to answer your question about the winds in particular. I'm in Omaha, and we had a very windy winter, more so than anything else this winter, I think, we were windy. But the wind is a factor of where the storm track is setting up. We aren't that great yet at deciphering what's going to happen in the future with wind. There are some potential for some parts of the country to have increased or decreased surface winds in the future especially here in the middle. We actually might trend toward decrease near the ground in the future, but those are a little tough to pick apart just yet.

Marty, would you like to add to that?

That was a really good answer. The variability that happens normally will still dominate our experiences on the 10, even 20 year timescale. But there are some conditions that are simply going to be happening more often, and our ability to detect that really depends on looking in the long, historical record. So if we keep updating our point of reference we may not notice the climate is changing. But if we continue to hold a fixed reference period, like the 20th century, it becomes increasingly apparent that temperatures are rising. And so that heat wave would be becoming more frequent. So that 's something that we would expect to see even in the next 10-20 years, and of course especially in summertime because the rate of temperature warming, although a bit less in summer, Barbara made that point, than in winter the variability in summer is smaller in general, so its ability, your ability to detect that change is stronger.

Now I want to just call out one item, and that's the drought. Because California and the southwest have been in a multiyear drought. And the question has been whether this is what the future looks like for, let's say California specifically; pick a state here. Three years, the last year years, have had below average precipitation. There has been, there's an active research going on to try to figure out how unusual is this. 1970s, 1975-76 and 1976-77 were two consecutive very dry years. Those two dry years consecutively still rank as the driest consecutive two in years in the instrumental record since 1895. But what does climate change have to do with the lack of rainfall in California, really is the question? And is the next 20 years going to see even less rainfall happening in California with most of that rain of course falls from Nov to April. And the answer as best as one can tell from the science of climate change is no, you would actually expect to see more precipitation in California during the rainy season, especially the core, in Dec – Feb. There's science that is showing that based on these new climate models. So the current multiyear lack of precipitation so to speak for the statewide California is not a symptom of climate change as best as we can tell, and is unlikely to be something to happen more frequently, that is to say lack of rain in the upcoming 10 or 20 year period. In fact, maybe rather the opposite. But again, temperature and temperature competes with precipitation for the amount of moisture that's stored in reservoirs or is in the soils and is important for agriculture, and Barbara touched on that. So there's these competing effects that moisture is pulled by increasing demand in the warmer climate, but maybe increasing supply in some areas, perhaps like California due to more precipitation.

Okay, thank you. Barbara, this is a question for you dealing with El Niño. This question was El Niño is associated with the holiday period. Why is that if the next one is setting up to begin in late spring/summer 2014?

That's a very good question. I'm going to flip back to El Niño slide here, too. El Niño's history long ago was that it was first observed by fisherman near the coast of Peru, and named it after the Christ child. El Niño means 'the boy child' because it was often peaked or show itself around Christmastime. And that's certainly still true. Typically, El Niño events does peak in the winter months, Dec through Feb or Mar or so. However, it can start to develop and the anomalies can start to show themselves as early as the spring or summer months. And then those in turn can start to influence the weather pattern. So while we expect a peak and the most strong influence through the winter, we can start to see them develop quite a bit earlier than that.

Okay, thanks. Another question that we have gotten was dealing with, and I'm sorry for what slide number this is. This is a Marty question. This is dealing with the billion dollar weather, I think it's slide nine.

Okie doke… Yup.

I'll go ahead since I have control…

Oh… gotcha!

Okay, so we've gotten several questions about it. First question is is the frequency taken on a state-by-state basis, so large states appear more vulnerable than small states in the map?

Let's see, can you ask that again?

Sure. Is the frequency taken on a state-by-state, so large states appear more vulnerable than small states in this map?

Umm… I don't think the size of the state is necessarily key here. Although sometimes the size does matter because we have more representatives in the House of Representatives that may be lobbying for disaster emergency claims. So Texas and California having that benefit, but you can also see some small states that are clearly, Tennessee, not that Tennessee's a small state, but I noticed it has severe storms. So Texas seems to stand out quite a bit, and Texas, of course, is vulnerable in many ways because of its agriculture. It's in a semi, part of the state is semi-arid, and so it's prone to drought phenomena. It is prone to the severe storm phenomena. It is prone to landfalling tropical storms, which is where the flooding by and large is coming from. So Texas is positioned in a place where it's exposed to a lot of meteorological hazards. And so taking that as one example, maybe leave it at that. I just took Texas as a counterexample for the argument.

Okay. Another question dealing with this slide is one person asked if the billion dollar event is in constant dollars?

Yeah, that's a really good question. I'd have to go back and double check whether that has been adjusted for inflation. Of course here we're not looking at a time series, and in the time series you would want to be adjusting for the inflationary effects. I know that is taken into account. I don't know how that was specifically taken into account in this particular figure. So the value of properties has increased, and so that would lead to in the time series an increase in the high cost of damages. But some of these events, by the way, are so large in magnitude they exceed by a large amount a simple billion dollar threshold. There's no doubt when these certain events have been happening.

Okay. The last question dealing with this slide is people were asking about its availability. Is it somewhere on a NOAA site that it could be downloaded? Several people have said that this would be great in various presentations to use for internal and external audiences.

Yes, the NOAA National Climate Data Center monitors and creates this, monitors this field and creates this image. So this image is available through the National Climate Data Center. I don't have a url to this particular picture directly. But we can offline talk, and I can see if I can find it and then you could share it.

Great! Thank you, Marty! Another question that we have gotten, and this both you, Marty, and Barb. Question dealing with the models. I have read that the models used by the IPCC have not yet been able to include all of the very complex natural and human caused factors that can be causing the more rapid than predicted increase in temperature in the arctic region, and therefore the more rapid loss in the Arctic sea ice. What is being done to improve these IPCC models regarding this phenomena, and how long will it take them to make that improvement? Furthermore, is there a way, anyway to make assessments of Arctic changes to seasonal weather besides the reliance on models?

Would you like me to start with that one, Barbara?

Go ahead.

So the Arctic is a region where NOAA is only invested on many different fronts. There's the picture of the sea ice. It has interests in terms of ecosystem, of course we have the regional weather service in Alaska, the fisheries, we have the navigation. There's a great interest. NOAA's invested in getting the Arctic well monitored and well understood in terms of how it's changing, and then also what the impact of the Arctic has on the rest of the world. The mention was that the models, and what I assume is that what is being called out is that the sea ice depletion which is schematically seen in that figure is somewhat greater than what the climate model projections, or I should say simulations from the IPCC have indicated to date. And that is only partly true. The sea ice depletion, the rate of its depletion the last decade is on the low end of the average of about 37 or so models that are being used in this assessment. So if you look at each of these 37-some odd models, you'll find a couple examples, not many, that are also declining as quick as in the observations. What's being found is that the rate at which that decline in the models occurs depends very much on how thick the ice is within the model that is being used. So some of these coupled models, which are very sophisticated by the way, the sea ice is a fully predicted variable; its thickness, its spatial coverage, its albedo, the clouds and so forth above it. These are very advanced models, but some of them have a thicker sea ice to begin with than other models. The ones that for whatever reason, some bias in these models, creating thicker ice show less sensitivity initially, and some that have thinner ice to begin with more quickly respond and show a declining rate that is in tune with what has been observed. Eventually, when I say eventually by about 2050, regardless of whether the model started with somewhat thicker or thinner ice in the year let's say 2000, they converge to a state of almost ice-free Arctic in the late summer. So the trajectory downwards is demonstrably due to climate change because all of the models are doing it. Some are as rapid, but most are not as rapid as observed. It could be because of biases I mentioned. It could be because the observed rate of decline is not entirely due to climate change. So there's other factors that do cause sea ice to vary.

Barb, do you have anything additional?

Just one small point, and that goes back to the beginning of the question about IPCC not able yet to include the very complex natural and human caused factors. You know, models come a long way as they go under development, that's true of both weather and climate models. And in both cases the further we go on, and the more we invest in our modeling systems, the more that we are able to more closely replicate all of the physics of the atmosphere that we have and understand, so including for example, not just the influence of volcanoes, but of human soot pollution that we put in the atmosphere and other such additions. So I just want to acknowledge the point that yes, it's very difficult to capture every human and natural phenomena. We are doing pretty darn good at getting the big ones, though, and the further we go on the more we'll keep adding the small pieces, too.

Okay, thanks. One more question before we go because are now getting into 20 after and I don't want you all to be too much longer. But this I thought was an interesting question. It's a very, it maybe a hard one to answer, but it's one that I know I have gotten and I'm sure several other people have gotten this past season. And here's the question: the Great Lakes as several other regions have as well have gotten hammered by snow this year. How do you respond to the people who say 'see, the globe isn't warming'?

That's a good question. Is it okay if I hop on this one first, Marty?

Yeah, you go for it.

Yeah, absolutely. We definitely had a colder and snowier than normal winter across a good part of the country. Many places set records for either the cold or the snow. So how do you mesh that with climate change in a warming planet? And the best answer is you know as warm as the planet will get winter still happens, especially in places that already get winter. There will still be years that we get colder than normal, significantly colder than normal. We will continue to set cold temperature records, but what we do expect to see is for that to happen less often. And there is a great graphic that the National Climatic Data Center put together that I don't have in my presentation. But what it showed is that, yes, this winter was about as cold and snowy as the ones in the late 70s in the region, which for those of you who remember this time was pretty darn cold and snowy. But winters like that used to happen a little more frequently, and if you go back to say the 1800s, they used to happen a lot more frequently. This used to be more of a normal state of the winter. So while we expect these extremes to continue to happen, they are also at least in our records and models into the future, they're expected to happen less often the further we go down the path of a warming planet.

Now that's good. I think it gets at the heart of the answer. A few numbers to toss out. So the Great Lakes is a small part of the world. I used to live in Madison, so I love the area, so that's not a diminutive statement. So it can be quite cold in some area, but the globe as a whole can still be going in an opposite direction, i.e. warmer. In the winter of 2013-14 that just finished the globally averaged temperature, I believe I don't have exactly the number, but it ranked in the top five I believe it was. May've been second or third or so in terms of the ranking since the late 1800s. So the globe was warm. The occurrence of the cold winter was an unusual event. In the warming planet as a whole we saw the time series in Barbara's talk the warming trend in the Midwest region is demonstrable. The fact that we had a cold event was a rare event probably. It's fair to call this a rare event in a warming world, but still an event that can happen as obviously it did. Some have tried to actually twist it in a different manner. Some have said 'you see these cold waves are also consistent with a warming world'. So I phrased that question a little bit differently than what was given to us, Jill. Is the cold wave that happened itself an expression of a warming world? Will we have more variability? Will extremes of the cold and warm side increase? Which actually is somewhat of a more interesting question. And I'm not going to try to give you the complete answer on that, but that was the question that was tossed out in part by some, I think, who maybe felt compelled to even argue that you know, we expect extreme cold in a warming world, and I think that kind of got confused with the idea that gee, how can that happen? But I think there was this feeling of responding to this question of maybe dismissing the global warming because of the experience of the cold Great Lakes winter. In fact, we expect cold waves to become less frequent. We expect events like this over the Great Lakes that happened in this year to become less common. The fact it did happen this year was very unusual, and will become even rarer as we go forward.

Marty, I'm going to add just a bit to that because you made some really good points. First of all, yeah, thank you for pointing out that we were a small cold pocket in an otherwise very warm winter in a lot of places. And Mar, I just pulled up the NOAA email, Mar was the fourth warmest since record keeping began. So Mar itself ranked quite a bit up there, and the rest of the winter was also on the warm side across the globe, too. And Marty, you also made a good point about is this what we expect in climate change? And for temperatures I'd say not so much. But I want to point out precipitation. That precipitation trends are increasing, too, and that's especially in the winter months. Well what happens in the winter in the Great Lakes when precipitation falls? It's generally not falling as rain, it's falling as snow in a lot of cases. So if we're expecting increased precipitation in a cold climate in the winter months we are likely expecting the potential at least for increased snow in the future at least for a while until temperatures catch up to it and start melting it off a little bit. So these are areas that are still under study, still understand these and investigate them, but it helps put the whole picture together of climate change, you know, it does link to at least some impossibility of increased snow potential in the winter there.

Thanks, Marty, Barb. This has been a great, these have been great presentations. We really appreciate it. I really want to thank you for your willingness to talk with us today about your work. It was really an excellent discussion.

Thank you!

Thank you for having us!

Well thank you! Unfortunately we have some more questions, but we have really run out of time and I don't want to extend our welcome, so I really appreciate it. So I wanted to just close real quickly. Thank you to Marty and Barb for their willingness to talk with us. Also, a thank you to Ohio State University, the National Sea Grant College Program, and Ohio Supercomputer for funding this webinar. I did want to remind everyone that our survey url for this webinar is in the 'chat' feature, so please take a few minutes to fill that out. I also wanted to refer you to resources and an archive of all previous webinar presentations, which are located on our http://changingclimate.osu.edu/ website as well as our regional site at http://greatlakesclimate.com/. This webinar series is sponsored by the OSU Climate Change Outreach Team, and we'll continue next month with scientists from the University of Wisconsin and University of Maryland to discuss climate change impacts on wildlife. The registration is up in the 'chat'. Thank you again to Marty and Barb and all of the participants on this webinar. We hope that this was beneficial, and hope you'll join us again in an upcoming webinar. Thank you again Marty, Barb. That was great! And have a great weekend or afternoon!

Thank you!

Bye!