EPA Urban Heat Islands Webcast
April 29, 2008

Slide 1: Agenda for the National Urban Heat Island Webcast

Eva Wong: Ok, well I have 2:01 on my watch, so I guess we can get started. I'm Eva Wong at EPA, running the Urban Heat Island program here, and I want to welcome you here to our second webcast. Before we were having national conference calls, but now we started this webcast format. And just to remind you about the agenda for call – I'm just going to spend a few minutes walking through the logistics of the webcast Live Meeting software, how it works, because I'm sure we have a couple of new people who haven't used Live Meeting before. Then we're going to hand it over to Dr. Brian Stone, followed by Dru Crawley, and then Sara Espinoza is going to wrap it up in terms of formal presentation of the slides. Then I hope, if there's remaining time, we can kind of just go around and give each other updates on the work that we're doing, because I always think it's nice when we have so many experts and people of related interests on the line to just use this as an opportunity to talk.

Slide 2: Live Meeting Logistics

Eva Wong: Moving on to my next slide. Please, during the presentations, if you could mute your phone by either using your own mute button, or by pressing *6. That would be great, because there's so much background noise it's really disruptive, so please do mute your phones - *6 or use your own mute button. And when you want to speak – which we'll allow time for Q&A after each presentation – if you could press *7 or just un-mute your mute button on your phone. If you want to see the full screen and not see all of the different pop-up or drop-down boxes, you can press F5 to show the presentation full screen. And then to go back to the Live Meeting console, you press F5 again. As I was noting, you'll have an opportunity to ask questions after each speaker. You can just un-mute your phone and just ask the question. Or, if you want, you can actually use this "Feedback" drop-down menu, which we're going to talk about in the next slide. If you're interested in seeing who is participating in the webcast, there's an opportunity to view the Attendee list, and maybe many of you already have that open on your computers. During the webcast, if you're having problems, or I know a couple of people were saying they couldn't access the webcast feature because they had Macintosh computers or whatever, Nikhil Nadkarni at that email address or telephone number can help you out. Or he can send you the powerpoints if you need them, or help you out with any difficulties.

Slide 3: View and Layout

Eva Wong: Now in terms of view and layout – this is hopefully what you see on your screen. And again, as I was saying, press F5 to see the full screen, and F5 to return to the Live Meeting console. And to restore all defaults – if something happens or you don't know what happened – go to the "View" drop-down feature and select "Restore Default Layout" from that drop-down menu under "View", and that will restore everything to its old settings.

Slide 4: Feedback and Questions

Eva Wong: Next – for feedback and questions, as I was saying you can just ask them, or you can try to use the feedback or question box features. So you can either just change your color – right now, everyone is on green, which is saying things are going fine, you don't need the presenter to slow down or everything is at the right pace. You can change your color – there's a drop-down menu that says "Feedback to Presenter" – you can change that to purple if you have a question, or if you need the presenter to slow down change your color to red – so here that circles that feature. If you want to just narratively ask your question, you can type it in that box that's circled in that long – the example is circled in the oblong red circle. So you just type in your question, and then you press "Ask".

Slide 5: Attendees

Eva Wong: And then lastly, as I say, you can view who is attending or participating on the call, which I always like to do to see who has called in. You just click on the "Attendees" drop-down menu and you should see that. Those are basically the logistics. I hope that's all clear. Next, we're going to hand it over to Dr. Brian Stone. Brian, are you able to click onto your presentation now? Do you have that?

Slide 6: Urban and Rural Temperature Trends in Proximity to Large U.S. Cities: 1951-2000

Eva Wong: Just to review, Dr. Brian Stone is an Assistant Professor in the City and Regional Planning Program at the Georgia Institute of Technology. And we're very glad to have him here, so Brian, please go ahead.

Brian Stone: Ok Eva, thanks, I'm thrilled to be with all of you in the comfort of my office. I am a bit of a novice at the webcast, which is amazing technology. I will look for purple boxes – I can't promise I'll see you, so I'm happy for you to just interject if you have a question, and I'll answer it while I'm going. Or I can answer it when we get to the end, when we get to the Q&A, I will look to see if any purple boxes come up. I'm going to be talking today about some recent research that is focused on the rate at which urban areas are warming, and whether this rate or whether urban areas in general are starting to amplify background rates that we might associate with the global greenhouse effect.

Slide 7: Overview

Brian Stone: I'm going to focus on four general topics today. I'm going to talk about mechanisms of climate change just briefly. My sense is that most, if not all of you are familiar with the global greenhouse effect and how that differs from the urban heat island effect, but I know we have a range of backgrounds. So I'm just going to touch on that and highlight one point I want to make. And then I'll talk about how I've measured what are called urban warming trends in this study, and then present the results, and then just talk briefly about what are the potential planning implications of these findings.

Slide 8: U.S. Temperature

Brian Stone: Starting with this slide number three – this is the annual temperature anomaly data that's reported by NASA every year. And this is probably the most widely recognized evidence of global warming people see when NASA comes out and says, 2005 was the hottest year on record, or 2007 was one of the top ten. And this is the data set they're working from. This is just the U.S. data, but they also have a global data set. And so I want to talk about in some of my time, how they are deriving this information, and whether this trend we see – when we see this kind of rapid increase in temperature starting in the late 1970s – whether this is capturing is what's happening in large U.S. cities, or whether the urban trends might differ from those somewhat.

Slide 9: The Greenhouse Effect

Brian Stone: I wanted to start with this slide on the greenhouse effect, just to highlight one significant point here. When we think about the phenomenon of global warming, it's actually a product of two distinct physical phenomena. One is what we most commonly talk about, and that's the accumulation of greenhouse gases in the atmosphere, and what is happening with the trapping of outgoing long-wave radiation. We have the incoming short-wave radiation from the sun, which passes through the greenhouse gases – they're transparent to the radiation. But then the long-wave radiation is being emitted from the earth's surface, which of course is being trapped and being reemitted and creating this warming effect. We can think of that as the atmospheric warming mechanism. There's a secondary mechanism that's happening here, and this graphic captures it with this horizontal arrow across the land surface of Europe in this case. And that is that we're modifying the surface characteristics on the planet as well, and that's also contributing to warming. So deforestation, that is either making way for agriculture or urbanization, and things of that nature are increasing surface temperatures as well. And so, where we'd have an accumulation of greenhouse gases with no land surface changes, we would theoretically expect to see some rise in temperature. But also if we were to see land surface changes that were increasing surface temperature without any accumulation of greenhouse gases, we would also expect to see some warming. So both of these are independent and they're not always emphasized in the research.

Slide 10: Land Surface Change

Brian Stone: And this next slide is just illustrative of these changes – deforestation in the Amazonian basin, for example, is driving an increase in surface temperatures, and so is urbanization.

Slide 11: Impact of Urbanization and Land Use Change on Climate

Brian Stone: There's been little attention, or not a great number of studies that have sought to tease out theses two phenomena, which is contributing more to the rise in temperature that we see in near-surface air temperatures. This is one study that was published in *Nature* a couple of years ago that uses an interesting methodology. In this case, they're using weather balloons to measure essentially upper atmospheric temperature measurements. And they're comparing that to near-surface land measurements and they're teasing out the contribution of land surface change. And in this case most of the weather stations that are there are in the eastern half of the U.S. But what they found is about 50% of the rise in near-surface air temperatures since the 1960s is attributable to land surface change. And that's a very important finding, if accurate. There are some important critiques of this study, and there are not many to back it up. But it raises the question of how significant is land surface change to the temperature changes we're seeing? So in this study I'm asking a somewhat similar question, and that is if we look at temperature change in large cities there are two components. One is the urban heat island effect, which is driven in large part by land surface changes, and the other is the global greenhouse effect. Both of those are theoretically contributing to change in cities, and which is more significant? So I'm essentially trying to measure how much, or to what degree, urbanization is amplifying background rates of warming.

Slide 12: Global Historical Climatology Network

Brian Stone: To do that, I draw on a dataset that was developed by NASA – it's the same dataset they use to create the temperature trend data that I started with. And their dataset is drawn from a very large global network of both sea and land meteorological stations known as the Global Historical Climatology Network. And so what I'm using is a subset of these meteorological stations, and I'm looking at data from the 1950s to 2000. Now to do that – to measure temperature over 50 years – requires very high-quality data. And so, in terms of the U.S. stations, what we draw on are known as first-order weather stations.

Slide 13: Sources of "Inhomogeneity" in Temperature Record

Brian Stone: And these are weather stations where the staff has been certified by the National Weather Service, and the instrumentation is periodically validated. And in particular, and this dataset that NASA has developed, four sources of bias – or "inhomogeneity" is the technical term, but essentially they're just correcting for bias – have been addressed in the data. And there are four things. If we think about measuring temperature over 50 years, there are lots of external changes that could create a bias in the temperature record. For example, you could physically move the weather station. You could move the thermometer. If you were to change the microclimate or the elevations, that would create a shift in the long-term temperature record that would be attributable to something other than climate. And so it's important to have data where that source of bias has been corrected for. Change in instrumentation – we know that weather instrumentation has become more precise over time, and so that can create a shift in the long-term temperature trend. Change in the time of observation – when you're measuring temperature over what averaging time needs to be accounted for. And then this final one – contamination by urbanization – and contamination is the technical term. And this is describing the bias that's a product of the urban heat island effect. And so – and this is a particularly important point for this study, in that the datasets that have been used to study global and national temperature trends are actually removing urban meteorological stations from the dataset, or they're statistically adjusting them to remove the influence of the urban heat island effect. Now there are two reasons to do that – at least two that are significant. If you are interested in measuring the phenomenon of atmospheric warming, if you're interested in measuring the contribution of the accumulation of greenhouse gases to warming over time, then you want to correct for the land surface changes that are also driving temperature change. And so it makes sense to adjust your temperature observations in the places that are experiencing the most significant changes in terms of land surface. And then secondly, if you're interested in measuring average warming globally – so if you want to get a sense of how much is temperature changing in an average location on the planet's surface – well, urban areas are not an average location. They are a rather anomalous location. Urban areas still account for a very small percentage of total land surface, and so if you're interested in average temperature change the urban measurements will serve as outliers and they will bias your measurements. So it's possible to get these data from NASA with both the correction for urbanization and without. And so what I'm doing is, I am acquiring the data for urban weather stations that has not been corrected, to get a sense for whether the trends in cities are different than the trends in rural areas.

Slide 14: 50 Cities Included in Study

Brian Stone: So, in this study I've identified 50 large cities – these are 50 of the 60 largest metropolitan areas in the U.S. And you may note on the slide that there are some important cities that are missing. Chicago is missing, San Francisco is missing. These are cities that are among of course the 50 most populous, but for which we do not have a consistent temperature record that has been corrected back to 1950. And so in the case of Chicago, there actually is not a single dataset that goes back to 1950 that I could use, so I had to eliminate it. So what I end up with are 50 of the 60 most populous – these are the cities or regions for which we had this long-term temperature record.

Slide 15: Hartsfield-Jackson Observations

Brian Stone: This next slide, number 10, is what the raw data actually looks like. And this is data from the Atlanta station, the Hartsfield-Jackson Airport observations. And this shows a trend that's consistent with – at least in form rather than actual magnitude – that is similar to most of the weather stations that we see. And that's that we see a general increase throughout the early half or first half of the 20th century, and then a rather significant reduction in temperature in the 50s and 60s and 70s, and then we start to see an increase again in the 80s and 90s. And there's a specific climatological phenomenon that's driving that dip that I'll talk about in just a minute, but I just want to give you a sense of this is what the raw data looks like.

Slide 16: Station Selection

Brian Stone: And I'm acquiring this for a single urban weather station, and three rural stations that are in proximity to each city. So the station selection criteria are important. And I start off with first just trying to distinguish between what is urban and what is rural. And a very useful piece of data to do that is the surface luminescence that is captured by a military satellite. And this is what – you've probably all seen this image – this is what the U.S. looks like at night from space. And so NASA has gone through and ranked every weather station as far as whether it is bright, dim, or dark. So dark receives an "A", dim a "B", and bright a "C". And so weather stations that are in urban areas are those that have a night light ranking of "C". And in this case I had very few options – if you look at the corrected data for major cities, there's usually only one and sometimes just two weather stations that have been corrected. And in almost all cases this is the airport. And so for these urban stations I'm using the airport meteorological station, which creates its own significant biases and limitations that I'll talk about over the next few slides. And of course, only using a single weather station to represent an entire metro area is also very problematic, but it's the data that's available back to 1950, but we need to consider that when we evaluate the results here. The rural stations are selected based on three criteria: night light ranking of "A" (dark in most cases) or "B" (dim) if a dark station was not available; low population densities (less than 4,000 per square kilometer); and then located within 50 to 250 kilometers of the urban weather station. Let's look at an example of the airport data in the case of Atlanta – just again it is Hartsfield-Jackson, Atlanta's airport. And this is characteristic of almost all of the airports – in fact, all of the ones I've looked at in this case – is that the weather station is upwind of the airport. And so the objective in positioning this is to capture incoming weather. To measure incoming weather over the field that gives you obviously useful information about landing planes and managing the airport.

Slide 17: Hartsfield Meteorological Station

Brian Stone: In terms of the immediate surroundings, in this case, it's not in the middle of the tarmac obviously or on top of a building. The immediate surroundings in this case are a grooming field about 100 yards off of the runways. And so this is going to be influenced both by its immediate climate and the larger climate in which it is located. If we look at the region – the airport is south of the city, and so the question of course that becomes important is: is this a good surrogate for Atlanta? If you only have a single meteorological station, is the airport a good surrogate? In one sense it's not, in that it is not right downtown in the central business district, and so it's not going to be capturing temperatures that are consistent with that. But if we think about the actual land cover materials, they are largely consistent with what we would see. We see lots of impervious cover, very few trees, consistent with what we may see downtown.

Slide 18: Surface Temperatures

Brian Stone: The best test of course is to look at the actual surface temperature data. And we can do that with data NASA recorded in the late 1990s. "CBD" is the central business district of Atlanta, the downtown district. And if we look at surface temperature and compare that to around the airport you see some of the runways in the image of

Hartsfield-Jackson and some of the administrative buildings and terminals. What we see is in general the central business district – in terms of just surface temperatures – is higher; on average we're seeing higher surface temperatures. And so in this one case – and this is one out of 50 but I think it's largely consistent with what we see in all these cases – is that the airports are generally, in terms of your surface temperature, underestimating what we would see downtown. And so in that sense the results of the study may be somewhat conservative, but you have to look at this in terms of each actual metropolitan area. So it's an important point to consider, I just wanted to spend a few slides on that.

Slide 19: Urban Trends: 1951-2000

Brian Stone: So I'll move on to the results. I have a few slides of these national maps, and I want to help you decipher this – it's a lot of data to digest in a single slide or a few slides. This is measuring the urban trends, so this is the temperature change measured on the level of the decade for these 50 urban airports, the urban weather station. And what this is showing is that, averaged over the five decades, the average change in temperature was about 0.2°C per decade. So over the fifty years, about 1°C temperature change that increased on average for these cities. Now of course there was variation. For most of the cities we saw an increase in temperature in this time on average. For some we saw a decrease – we see this in a number of cities up in the northeast – Buffalo, Rochester, Syracuse, Pittsburgh, for example. What this means is not that these cities necessarily have been cooling off, or cooling off in the last twenty years. What it does mean is that what we've seen during this period of time, from 1951 to 2000, are trends in which we saw temperatures increasing, periods in which we saw temperatures decreasing, and for these cities the cooling trends are the dominant trend.

Slide 20: Pittsburgh

Brian Stone: And so a good example of this is Pittsburgh – to look at the raw data again, which we see here. We see this characteristic dip in temperature in the 50s and 60s and throughout most of the 70s and then an increase. What we're looking for here in terms of these red and blue dots is the average temperature pattern from 1950 to 2000. In the case of Pittsburgh you had both cooling and warming, but you had more cooling than warming. And so we end up with, on average, is a blue dot which is indicative of a predominance of cooling.

Slide 21: Pacific Decadal Oscillation (PDO)

Brian Stone: Now why are we seeing this dip? We see this in all of the datasets. There are potentially a number of reasons, but the most likely is an association with a phenomenon in the Pacific, known as the Pacific Decadal Oscillation. This is essentially a long term El Niño/La Niña phase. It happens on the course of decades rather than on the course of just a few years or months. It's reflective of changes in sea surface temperatures, it's a long term oscillation, and it has significant and measurable implications for weather throughout the continental U.S and other parts of the globe. And so what we see here is in the 50s and 60s and 70s is largely a negative phase.

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Brian Stone: And this contributed to, in some part, the dip in temperature that we see in Pittsburgh, that was particularly pronounced in a place like Pittsburgh.

[Back to Slide 19: Urban Trends: 1951-2000]

Brian Stone: And so why it was more pronounced in Pittsburgh than perhaps some of these other urban stations, I would not pretend to be qualified to say. I'm not sure that the science is sufficient today to tell us that, but there are potentially a number of reasons. But in general what we see is this dip in the decades of the 50s, 60s, and 70s that is most probably correlated with the PDO, let me say not correlated but driven by it. And that's having a more pronounced influence in some places than others. So that gives you some bit of a sense of understanding the red and the blue and the trends.

Slide 22: Rural Trends: 1951-2000

Brian Stone: The rural trends – the slide I have up now – is showing again in most of the rural weather stations – and again these are the three weather stations in proximity to each urban area that had been averaged – we see in most cases a predominance of warming over cooling. The average rate of warming over all of these cities was 0.15°C, so lower than we saw in the urban stations. And then somewhat of a shift – we have a number of stations in the southeast or in the southern latitudes of the country where we're seeing more cooling than warming in the rural stations.

Slide 23: UHI Trends: 1951-2000

Brian Stone: And so the objective here is to subtract the rural trend from the urban trend, and that's what we see here. And on average we get a mean decadal change in the urban heat island of 0.05°C, and I'll talk in a minute about providing some context for that number. But what this shows is again on average we're seeing an increase in the intensity of heat islands over time. Now the blue that we see here – the blue circles – are not indicative of places that no longer have heat islands. They are indicative of places where you're seeing a convergence between rural and urban temperatures, and I want to give you an example, because I know the data can be somewhat confusing if you're not used to looking at these types of studies.

[Back to Slide 19: Urban Trends: 1951-2000]

Brian Stone: But let's take Philadelphia, which has been in the news a lot lately, not for climatological reasons. But we can see Philadelphia, in terms of the urban trend in this slide, and we see a medium- to small-size red circle suggesting that the urban weather station has been warming – there's been a predominance of warming during this fifty-year period.

[Back to Slide 22: Rural Trends: 1951-2000]

Brian Stone: If we look at the rural trend, it's a red circle that's a little larger. And so what we're seeing is that both the urban weather station and the rural weather stations are increasing in temperature over time. But that the rural weather stations are increasing in temperature more rapidly. Now that's interesting, and it raises lots of questions about why that might be the case.

Slide 24: UHI Trends: 1951-2000

Brian Stone: We see significant clusters in this slide, in terms of the UHI trends. Where we see, in the Northeast, this cluster where we have a convergence between urban and rural temperatures where heat islands are diminishing over time. And we see just the opposite in the southern latitudes, in the Southeast and into the Southwest. Now I can only posit as to why that might be the case. There are competing theories – at every conference I go to I get a new one that's also compelling. But I'll tell you the one predominant trend that I see is that these cities in the Northeast have been losing populations for the most part from 1950 to 2000 – certainly not growing as rapidly as we see in the Southeast or in the Sunbelt cities, and in many cases, actually losing populations. What that may mean – and again this is speculative, because I don't have the data to tell me definitively – but it may mean that we're seeing somewhat of a regeneration of vegetation within the urban areas. And that could mean that they are warming less rapidly than they might have historically, and that they are diminishing their rate of warming, while the rural areas are warming at a constant rate. And that could lead more to a diminishing of a heat island. There could be other drivers here. In many of these cities we have old coal-fired power plants that are right downtown. This could be increasing aerosols, and creating a localized coaling effect. Again, I can't tell you exactly what's driving this phenomenon. I *can* tell you that there's a statistical difference between these two areas that's interesting – it's somewhat of a secondary question for this study, but it's definitely worth highlighting and raising that question, because I know we have lots of expertise on this call. So maybe others will have greater insights than I do into that.

Slide 25: Rate of Temperature Change 1951-2000

Brian Stone: To provide some context for what I've found overall. This chart is showing estimates or measurements of temperature change at different scales during this same period, 1951 to 2000, at the global level – and this is reporting temperature change in degrees Celsius per century, so I changed the unit on you and moved that decimal place, don't get confused by that. But the globe during this period of time increased by about 1°C. The U.S. increased by a little bit more than that, 1.7°C. And then what you see in the next two bars – the rural and urban – are the data that I just reported, which is showing from the rural weather stations, which is a subset of the stations used to produce the U.S. number, about 1.5 degrees during this period of time per century. And I want that number – I'm hoping that number will be close to the U.S. number, because it's a subset of that same dataset, and it's reasonably close. And then the urban number here from my dataset, the 50 large cities, was 2°C, the differential of course being that 0.5°C per century. And then the last two bars are a subset…

[Back to Slide 24: UHI Trends: 1951-2000]

Brian Stone:…and these are just these cities with the red dots, about 60% of the data…

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Brian Stone:…the cities in which we see an increase in the heat island over time. For those cities, we see the urban rate of warming is more than double the rural. And this was also found to be a statistically significant trend, an important one for these cities because they are warming rapidly, and suggesting that they are likely to exceed the global forecast for warming over time, and that they need to be prepared for that. I'll talk about that in a minute

Slide 26: Amplification of Warming Attributed to Urbanization in U.S.

Brian Stone: Other studies that have looked at changes in the urban heat island over time – there are not many, and this is not all of them – these are some of the important ones that are most comparable to my study. The first is one by Jim Hansen – and again, he is responsible for the dataset that I'm using. I'm using a subset of the larger dataset that he has created at NASA and used for his temperature anomaly observations annually. Measuring – this is not directly comparable – but this is showing the growth in heat island. We can take this over time. This dataset is looking from 1900 to 1999, so it's looking over a longer period of time. And we know those earlier decades in the 20th century there was not as much warming as there was towards the end. And so by looking at that period of time we'd expect somewhat of a lower number. The Gallo et al. study of about 0.26°C per century was not found to be statistically significant, but nonetheless I included it – and it includes a much larger number of small cities. And so the reason this number is lower could be because it's including smaller cities, but then again it could be something else that I'm not seeing. The Kalnay & Kai study is one I referenced before. It uses a very different methodology and finds the rate of warming in cities as amplification, as characterizing it here of about 0.35°C, and then my study of about 0.5°C per century. So again, my study is unique in that it's looking only at the largest U.S. cities, and is different from each of these. But in terms of theory, it's not surprising to see that larger cities would not only generate larger heat islands – that's found in other studies, I'm not saying that here – but that the rate of warming would be higher.

Slide 27: Study Findings

Brian Stone: So the findings – on average, the decadal rate of warming in large U.S. cities was about 30% greater than that of proximate rural areas taken to represent background warming rates. For cities in which the heat island effect was enhanced during this period – that's 60% - the decadal rate was about 150% greater than that of proximate rural areas. And that's a large number – suggests a significant increase in the rate of warming over time, which should be of concern. As warming scenarios developed by the IPCC are based on background global rates – again, it's largely a rural network or it's one that's statistically modified the urban trends. The scenarios forecast are likely to significantly underestimate – particularly when we look at this subset of cities – the rate of warming. And so what's forecast here is an increase of 1.4 to 5.8°C by 2100. If these data are correct for not only these cities, but global large cities, then that would suggest that large cities are going to be warming by more than this, and that we need to be preparing for that.

Slide 28: Expected Rise in July Average High Temperature (F) by Scenario (Atlanta)

Brian Stone: Now to give you an example – and this is dangerous territory, but I think it's useful to look at this. If we extend this trend forward, which is a simple linear extrapolation which assumes that heat islands grow on average at the same rate they have historically – which there's no way to know if that's true. But if it is true, this is an interesting analysis, and it's just for the city of Atlanta. And it shows that we can choose somewhere in this range of 1.4 to 5.8°C for the IPCC projections of the planet as a whole – and what this shows is a 5 degrees, towards the high end of that range, but this range continues to be increased over time. So if we assume that over 100 years we're going to see about 5°C of warming (that would be about 9°F), that's the IPCC number, the question is: should we assume that number for places like Atlanta? If we look at the average city, in this study, it would suggest an increase in that number by a factor of 1.3, an increase of about 30%. Again, that's what I found over the last fifty years, so if we project that forward and assume an amplification of 30%, then we'd see an increase of about 12°F in these cities. For the subset of cities that were found to be experiencing an increase in the intensity of the heat island over time – that would increase to a factor of about 2.5. So in this case, it would be about 23°F, which is really an extraordinary number, and it illustrates the dangers of using a trend extrapolation, but also highlights something that is within the realm of possibility based on historical trends, and it's something we need to be aware of. So in the case of Atlanta – if we took an average high for Atlanta it would be about 89 degrees – and this were to occur, you would be seeing temperatures in excess of 110 degrees for a high temperature in the summer. And that obviously, were it to occur, would be a significant public health challenge. And there have been a handful of studies that have shown that this is within the realm of possibility, if we are accounting for both background global warming phenomenon and also the urban heat island effect.

Slide 29: Negative Feedbacks on UHI

Brian Stone: It's important to note of course that we don't know moving forward what will happen. There are lots of theoretical negative feedbacks that could occur. There is data in the present period to suggest that heat islands induce rainfall – we see this in Atlanta – and so this could have a negative feedback on temperature change over time.

There could be others as well that need to be highlighted – it's just uncertain – but one of the trends that we have a lot of confidence in as far as moving forward is that urban areas are going to grow rapidly. And in this particular study by NASA – and this is my last slide – more than half of the built environment of the U.S. we will see by 2025 did not exist in 2000, giving planners an unprecedented opportunity to reshape the landscape. Cities are growing extremely rapidly right now. And this particular study suggests that the footprint of cities, the physical footprint, could double over 25 years, which is astounding. This likely foretells dramatic growth in the heat island and potentially amplification of what's happening as far as background warming. So in terms of planning, we need to be thinking about mitigating the drivers of global climate change, but also of course adapting to temperature changes that are underway that are driven by global phenomena and are driven by local phenomena, driven by the heat island effect. And these results suggest that in large cities that might be a tremendous challenge. And so I think I'm probably out of time, so I will conclude on that note and be thrilled to answer any questions.

Eva Wong: Thanks Brian. I know that there are two questions in the queue.

Brian Stone: And now I'm seeing them, yes.

Eva Wong: Do you want to read the question and give an answer.

Brian Stone: Yes, I will read it. Here, first question. What are criteria used for rural stations? Are these stations within the metropolitan area, but less urban than the urban stations? If so, why not use true rural stations so that it's at least 100 miles or so from the urban core? And this may have popped up before I went to the slide – but the stations that are selected as rural are based on the three criteria.

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Brian Stone: One is that, in terms of its night light it is dark or dim, and in this case, because there weren't enough dark stations, that we know that with this particular dataset there's reflected luminescence. And so in some areas that are perfectly rural, you may have reflected light that makes them appear dim. And I actually did some statistical testing to see if there were any differences between dark and dim stations, and there weren't. I also looked at stations that had low population densities, and that are within 50-250 kilometers. So in some cases this would get me to your threshold of 100 miles, but in many not. I don't want to move so far away that I'm dealing with a different regional climate. And it's also finding a sufficient number of stations that are going to be representative of the rural area in proximity to the urban area. So the 50-250 kilometers was – and the number changed during the course of the study as I was trying to find three independent rural stations for each urban station, and so I had to have a wide range to do that – but again the goal is to get outside of the urban envelope such that there's no evidence, based on the satellite data, that you have urbanization occurring and that you have low population densities. But I'm sure if you wanted to put a threshold of 100 miles that might create somewhat of a different outcome, but it would be challenging to identify a sufficient number of stations I think. Does that answer your question? I don't know who asked it, or whether you want to follow up but I want to give you a chance. Jim Yarbrough: Hi Brian, Jim Yarbrough in EPA Region 6. Just to follow up real quick – did you also take in to account land forms that were there during certain times but maybe disappeared during certain times? I'm thinking about reservoirs, for instance.

Brian Stone: Yeah, that's a great question. The answer is no, and the other issue with that is you may have military installations that have been decommissioned that could be influential. And so looking, in terms of the large reservoirs, we did look to see that we weren't positioned immediately on top of a large lake or some other kind of climatological influence. But smaller water bodies and things like military installations – that may be hard to fully detect from the data we had – that could be a source of error. So does that answer your question?

Jim Yarbrough: Yes, thank you.

Brian Stone: Ok, let me move on to what I think is the next question here. How well do surface and air temperatures correlate? For example, you mentioned that surface temperatures at the airports tended to be lower than those in the CBD. Does this hold true for air temperatures? That's a great question. It depends on the conditions; it depends on wind speeds, humidity, a lot of meteorological characteristics. There have been studies that have found – in terms of measuring the urban heat island effect – that there is a correlation for sure between surface and air temperatures, but it's an imperfect correlation. They tend to move in the same directions, but under certain conditions they can move in different directions. In general, and in this case, I think it's safe to assume it's quite likely that you would have higher air temperatures – near-surface air temperatures – downtown. Not only because you have a greater intensity of impervious cover, but also because you have radiation trapping that's happening in urban canyons that are going down between the buildings that are further intensifying warming. And so it's probably a safe assumption that airports are underestimating the temperatures we would see downtown. That may not be true under all circumstances, but I think it's a safe assumption. Does that answer your question?

Eva Wong: It does, thank you.

Brian Stone: Ok, then finally: Did you look at mean temperature or were you able to separate trends according to maximum and minimum temperatures? That's a great question. The mean temperature is derived from the average of the maximum and minimum, and that's the way the datasets are compiled. In that case, it's probably not the most accurate way to measure the mean temperature, but that's how it's compiled in these datasets. And we did not look at maximum and minimum independently, we just looked at the mean temperature for this study. Looking at minimum temperature would probably be a better way to capture the heat island effect, per se. In all datasets, we didn't have available to us—for all of these weather stations—the maximum and minimum. And in fact, for the corrected data, the data that's most accessible to us, we wouldn't have had that for a number of stations. And so to be consistent we used the same variable for all stations. That is – oh, one just popped up here: looking at the infrared photo I noted a fringe around the runways, I know this is asphalt and that it is hotter. Question: how much effect or improvement would occur if all urban surfaces were concrete? Wow, that's a great question. I'm sure there are folks on this call that are better qualified to answer that question. I don't know. We know in general, if we're looking at new concrete and new asphalt – I might get in trouble but I believe this is the case – that the concrete has a higher albedo; it's more reflective. Asphalt, as it ages, increases its albedo. I'm not sure whether it reaches the same level of reflectivity as concrete, and would love for someone who knows to pipe up and tell me. But I think we would see a significant improvement on average if we were to change to concrete, but that's not my area of expertise on the materials, so I welcome someone else to help me out.

Eva Wong: This is Eva, and I guess I'll just interject that, as Brian was saying, concrete tends to darken over time, asphalt tends to lighten. And Lawrence Berkeley Lab studies have shown that in about five years they roughly converge around, I don't know, maybe about 0.25 – I'm not sure of the exact albedo reading. But I think the thing to know is there's a difference between surface temperatures and air temperatures, so while concrete may have a cooler surface temperature, there is this effect that you'll see with asphalt cooling off more quickly at night. Whereas concrete – I don't know whether it's due to its density or what the actual property is, the thermodynamic property – but it tends to more slowly release the heat. So they have different dynamics at work. And I think we've been very careful about not just saying it's all albedo, because you really have to look at other properties like density. So that's my two cents for that. I think we have time for one more question, and then I'd like to turn it over to Dru. So if someone didn't use the Q&A but wants to just verbally ask a question...

Deirdre: Can I jump in here? It's Deirdre from Sarasota County. Real quickly, are you noticing any trends, because obviously for urban planners, we're looking at them and we're trying to decide what is the more prudent course: to have density and build vertically, or to build horizontally. And it seems as though with caverns and heat trapping, vertical construction has its downfalls. Are you finding one being more useful than the other, or more positive than the other?

Brian Stone: Yeah, it's a great question. And to my mind, it's the one outstanding question that hasn't been addressed sufficiently in the realm of heat island research. And it's one for planning that's just absolutely critical. From my experience, it depends on how the question is asked, how we're measuring heat islands. I had a study a number of years ago that was looking at this particular question in terms of heat production within suburban and urban neighborhoods at the partial level, which was suggesting that – in terms of the total heat production and lower density environments on a per capita basis – it was higher. But of course, if we account for downtowns and the radiative trapping, and things of that nature, it's hard to tease that out. But I think it's critical, and I wish that there was a national pot of money – let me get in my plug right now for anybody who has influence in these things – to fund a study to focus on measurement, and to actually measure different urban areas in terms of their heat island characteristics. There have been a number of studies that have looked at two-dimensional urban-rural temperature difference, but there are limitations to that approach to measuring. So in my opinion, there's not a clear answer to that question today, and it's critically needed. So it's a great question, and I would welcome and invite others to weigh in here who may have a different opinion on that.

Eva Wong: Well thanks a lot Brian, we really appreciate it, and if people have additional questions, I'm sure they can just email you. Did you include your email by the way in your presentation?

Brian Stone: I think it's on the first slide.

[Back to Slide 6: Urban and Rural Temperature Trends in Proximity to Large U.S. Cities: 1951-2000]

Slide 30: Estimating the Impacts of Climate Change and Urbanization on Building Performance

Eva Wong: Ok thanks a lot, and now we'll turn it over to Dru Crawley, who is a team leader at the Department of Energy. He's in the Commercial Building Research and Development office.

Dru Crawley: Hi, and thank you for having me today. Sorry for the garbled byline there – what I was trying to show was that although I work in the Department of Energy, this work is work that I have been doing through my PhD thesis at the University of Strathclyde in Scotland. And what I've been trying to do is look at – my topic is using single-building-scale simulation to look at how it can be used in policy. And one of things that has come up is what is the impact on buildings. If you looked at some of the IPCC reports from 2000-2001, that period, there was not a lot of information on it – there was a lot on how buildings affected that and it wasn't really any kind of reverse, how buildings operations and energy use might be compounding the problem as we go forward. So that was part of what I was looking at. So I want to go through and show you some of the things I did to look at creating some artificial – but based on all of the measurements and all of the models that I could find – some weather files that I could use in doing some simulations and then looking at the impact, so that's what this is about.

Slide 31: IPCC Climate Change Scenarios

Dru Crawley: If we go on to slide 2 – just a reminder about the climate change scenarios that are in the IPCC. There were four major storylines here to represent different demographic, social, economic, and environmental developments. Some of it was things like "business as usual," aggressive energy and environmental interventions, etc. So depending on that you get different outcomes in terms of what the predictions of the models are. From that there are four scenarios based on those storylines that really represent the range of climate impact from least to best, given the information at the time and the models. If we go on then – of course there were a number of Global Climate Models (GCMs) that were run – Hadley from the U.S., and the CSIRO from Australia,