Alright, I think we should start, so welcome everyone and welcome to our fourth, the first seminar of the Yale Center on Content in House in for 2020, so today we are very pleased that you have Dr. Xuhui Lee from the Yale School of Environment.

So he’s the Sara Shallenberger Brown Professor of Meteorology, he’s also a director of the Yale Center for The Earth Observation, he also received the 2015 award for outstanding achievement in Balm meteorology from the American Meteorological Society. So without further ado, we will have Dr. Xuhui Lee.

Thank you, Kai and also thank you Rob for having me in this event. Let me see, how do I, can you see my screen Okay? Yes. That’s much better now, that’s much better.

So the work I’m presenting today and the title of my talk is Urban Heat Island Theory, Measurement and Mitigation. So somewhere in that order, so the title of my talk is Urban Heat Island Theory Measurement and Mitigation. So somewhere in that order, let me see if we can turn out the, let me see if we can turn out the, let me see if I can turn off my screen here. Okay, that’s much better and so the work I’m presenting today
0:01:51.3 –> 0:01:55.23 is really a collection of things done by folks
0:01:55.23 –> 0:02:00.23 in my lab, current members and also past members so far
0:02:01.66 –> 0:02:05.66 of my lab, some of them are actually attending this event
0:02:06.76 –> 0:02:09.93 and I noticed that this event is being recorded,
0:02:09.93 –> 0:02:10.89 that’s fine with me.
0:02:10.89 –> 0:02:15.08 There are a few slides where we don’t have where we can....
0:02:15.08 –> 0:02:17.66 Where I showed you a sort of unpublished results
0:02:17.66 –> 0:02:20.82 so if you’d like to, if you want to share this recording
0:02:20.82 –> 0:02:23.79 with folks, please refrain from perhaps
0:02:23.79 –> 0:02:26.853 not sharing that part to people.
0:02:32.1 –> 0:02:34.82 So many of you are familiar
0:02:34.82 –> 0:02:36.33 with this kind of projections right?
0:02:36.33 –> 0:02:38.75 Projecting for temperature into the future
0:02:38.75 –> 0:02:40.37 to the end of the century
0:02:40.37 –> 0:02:45.37 depending on whether we take the aggressive mitigation
0:02:46 –> 0:02:48.88 or scenario or more of a business as new your scenario
0:02:48.88 –> 0:02:52.49 we will end up with very different temperature projection
0:02:52.49 –> 0:02:54.81 in the low emissions scenario,
0:02:54.81 –> 0:02:58.88 we expect maybe 1.5 degrees of increase, decrease dialysis
0:02:58.88 –> 0:03:01.24 increase near the end of the century
0:03:01.24 –> 0:03:06.24 but in a more sort of aggressive emission scenario RCP 8.5,
0:03:08.31 –> 0:03:13.31 the projection is that four degrees of decreases of warming
0:03:13.62 –> 0:03:15.75 towards the end of the century.
0:03:15.75 –> 0:03:18.67 So that’s the kinda big picture.
0:03:18.67 –> 0:03:21.65 So what I would argue is that Heat stress
0:03:21.65 –> 0:03:23.42 is actually perhaps the most,
The biggest climate threat to humans in stress associated with climate change.

The reason is simple: we humans are warm-blooded animals. We have a biological limit we cannot overcome. In a warm climate we need to maintain a temperature differential of at least two degrees between the body and the skin in order to get rid of metabolic heat. So that's a physiological limit barrier we cannot overcome if conditions are such that we cannot maintain a skin temperature lower than 35 degrees, then we will suffer serious health consequences, even death without of course the help of air conditioning.

So that's the kind of the motivation for this kind of work off and of course we know that residents in the urban environment suffer an additional heat stress due to the urban heat island. This is sort of classic depiction by Jumoke of what an urban heat island looks like. If you have a bicycle for example you'd end up with this lecture.
and you move across a transect from rural to urban core.

You would record temperature variations such way lower temperature in outside city, as you move to the center of city you’ll register very high temperature while relative to high temperature and this difference between urban versus rural temperature temperature is really what we call Urban Heat Island or intensity of therapy to time. So that’s a well accepted sort of depiction of this phenomenon and so this is added heat that urban residents would experience, this is a sort of spatial view for urban heat island here actually in the city of New Haven, the urban unite is very patchy. I have high spots here and there and some low spots there. So the high spots in the archaea shotguns area, right? And then that’s this downtown area and then near the fringe of the city where you have a lot of trees, temperature is much lower. So that’s the kind of urban heat island parent that you see in New Haven. So why Urban heat island is a concern? Well, you can just simply consider a probability distribution of temperature, this is a probability distribution temperature
of maybe a rural background
and Urban heat Island would shift
this probability distribution just by a little bit,
maybe by one degrees on average, right?
But that one degree of shift in the mean
would actually create a serious consequence
in terms of heawave frequency
and let’s suppose the Heatwave threshold is here,
own this is per heatwave threshold
beyond which we will see problems
with mobility and mortality
and for Rural background, rural location,
this is the area under this curve
is your Heatwave frequency.
Now for urban land, the simple shift in mean due to
our heat
on it, would change that frequency a lot,
we increase that frequency a lot, right?
And the other thing that you should notice
of course as the urban heat Island,
urban residents will actually experience
a record temperatures not being seen by rural residents
so again rural temperature stops here on,
so this is a spread.
So, but in the city,
you will see temperature beyond the record, right?
The record registering in the background sites.
So that’s also another issue
that we should be concerned about Bob.
So that is really the motivation
for why we study the theory of urban heat island
and why we want to come up with strategy to mitigate urban heat island, alright?

So let me switch to give you a sort of review of theory of the urban heat island phenomenon. So this traits, they can be trace back to me many years ago to team Oaks textbook, in his textbook he listed the seven causes of urban heat Island of the seven, I highlight the four causes people consider it to be the major ones. The first one is increased absorption of short-wave radiation due to urban morphology and maybe due to the color of the landscape. The conventional wisdom is that urban land tend to trap more solar radiation so that’s a source of urban heat island. A second source of urban heat island of course is very easy to understand because there’s an additional heat, anthropogenic heat from anthropogenic sources from automobile driving, driving automobiles bills, converts chemical energy in fossil fuel to mechanical energy that mechanical energy eventually dissipates as heat to the environment, right? And so another important source of anthropogenic heat is a space heating. We heat our houses or use of air conditioning.
and they will generate heat and dissipate heat to the environment.
The third course is increased sensible heat storage on buildings and other facial structures can store energy solar energy, solar radiation energy in a daytime and that then they were released that energy at night causing nighttime urban warming, and finally not a major course is decreased evaporation You know that you’ll replace natural vegetation, replacing, replace trees with artificial impervious surface you reduce evaporative cooling power right? So those are the four sort of major causes of Urban heat Island and the, we understand those concepts in a conceptual way, in a qualitative way for a long time and so what we did was with a few years back was try to quantify those causes in a quantitative way. We believe, we know only by quantifying those causes that will then lay the foundation for sensible sort of measure of how to mitigate Binky Don.

So I need to sort of take a step back and introduce this theory called The theory of intrinsic biophysical mechanism, this is theory was first developer to actually, to understand how perturbation changes surface temperature, changes near surface temperature amid arm, this theory is extended to talk, to the study of urban heat Island
0:10:42.69 \textendash{} 0:10:44.433 So some key points here.
0:10:45.42 \textendash{} 0:10:46.253 So this theory,
0:10:46.253 \textendash{} 0:10:49.095 This mechanism really is concerned with the process
0:10:49.095 \textendash{} 0:10:52.39 which how surface temperature responds
0:10:52.39 \textendash{} 0:10:55.85 to external perturbation by external perturbation,
0:10:55.85 \textendash{} 0:10:56.96 I mean a number of things.
0:10:56.96 \textendash{} 0:11:00.21 It could be addition additional aerosols to the atmosphere
0:11:00.21 \textendash{} 0:11:03.81 that will block sunlight penetration
0:11:03.81 \textendash{} 0:11:06.944 and an intercept sunlight penetration.
0:11:06.944 \textendash{} 0:11:11.944 And it could also be a change of urban, change of landscape
0:11:12.469 \textendash{} 0:11:15.95 a land use change replacing say, forest, we some open-end
0:11:15.95 \textendash{} 0:11:19.57 or natural land by urban man
0:11:19.57 \textendash{} 0:11:22.47 so those are considered to be external perturbation
0:11:23.67 \textendash{} 0:11:27.023 and so he helped Bob understand this process.
0:11:28.201 \textendash{} 0:11:31.65 There are two key components to that.
0:11:31.65 \textendash{} 0:11:35.63 Why is one called a local Longwave radiation feedback?
0:11:35.63 \textendash{} 0:11:39.26 And the other one is a change in energy redistribution
0:11:39.26 \textendash{} 0:11:42.41 but in the service in the overlying atmosphere,
0:11:42.41 \textendash{} 0:11:46.8 I’m gonna explain those two processes in a little bit,
0:11:46.8 \textendash{} 0:11:50.78 so the way it quantified the surface temperature response
0:11:50.78 \textendash{} 0:11:54.29 is really just to do this sort of experiment
0:11:54.29 \textendash{} 0:11:55.77 or numerical experiment
0:11:56.86 \textendash{} 0:11:59.61 and then it goes quantified through measurement as well
0:12:00.84 \textendash{} 0:12:04.47 to the surface response really is the difference
0:12:04.47 \textendash{} 0:12:08.49 between temperature of old state before the perturbation
0:12:08.49 \textendash{} 0:12:10.43 and a new state after perturbation.
0:12:10.43 \textendash{} 0:12:13 So that’s what the perturbation temperature signal
is really the key here and we’re trying to quantify.
So let’s take a look at, so let’s go back to the case of deforestation study, right?

The interest here is to motivate your part by the new trying to send whether removing trees or adding trees or warm or cool the local temperature. So I, this is my favorite numerical example. This is a actual data collected over forest in Israel, semi arid climate conditions.

This is how much solar energy reaches the forest and this is how much get reflected through its albedo reflected away from the surface, some escape of course to outer space, this is just a top of atmosphere. Now if you remove the forest and replace for us with some Shrub land, shrub land is much brighter, has higher albedo and so it’s a short wave radiation well reflection will increase and so naturally you would think that the temperature would go down, right? Because now you have more or less short wave trapping solar radiation when the surface when we undergo what we call radiative feedback because when you have low absorption solar radiation, the surface cool and therefore they will have less Longwave radiation escaping to the from surface and eventually you will establish a new radiation liberate, right?
Cause that process, the longwave adjustment, it's called Longwave feedback, that's a negative feedback and so if you allow just Longwave a radiation exchange, only allow radiation exchange to occur between the surface and atmosphere, this is you can come up with a simple prediction. So the change of straight away radiation is dead ass that's your perturbation signal and the change of surface temperature Delta Ts right? This is a parameter called Local climate sensitivity, that's more or less a constant the number and so in this particular numerical example you would predict by replacing for us Shrub land you expect a coin of dot four degrees about five degrees, right? So that's an argument some people used to promote deforestation, they're saying deforestation actually maybe a good thing cause helps cool the local climate because a lot because of albedo effect, but of course that picture is not complete because in the real world, you not only how a radiative process irradiated feedback, you also have too what I called energy redistribution occurring between the surface and the atmosphere. So there are two processes; One is evaporation. Evaporation is a process where liquid water is converted to water vapor right?
So that happens near, at the surface.

0:15:25.48 –> 0:15:28.27 so evaporation that will take away energy,

0:15:28.27 –> 0:15:31.28 take away late night Tiki damage that will consume energy

0:15:31.28 –> 0:15:33.7 and then when vapor gets to the top

0:15:33.7 –> 0:15:35.64 above the atmospheric boundary layer

0:15:35.64 –> 0:15:37.39 and condenses to form cloud,


0:15:39.99 –> 0:15:43.71 So the process is a process of energy redistribution.

0:15:43.71 –> 0:15:46.43 It reduced screwed energy, taking away energy away

0:15:46.43 –> 0:15:48.88 from the surface, and then put the energy back

0:15:48.88 –> 0:15:50.61 into the atmosphere above the boundary layer.

0:15:50.61 –> 0:15:53.32 So that’s one energy redistribution process.

0:15:53.32 –> 0:15:55.44 A second energy redistribution process is connection,

0:15:55.44 –> 0:16:01.57 is really is due, is the result of an emotion result

0:16:01.57 –> 0:16:03.67 of triplet motion in the boundary layer.

0:16:03.67 –> 0:16:08.67 That process is dissipating energy from the ground

0:16:11.24 –> 0:16:13.433 to the lower atmosphere.

0:16:15.141 –> 0:16:18.3 So you can set up this kind of thought experiment

0:16:18.3 –> 0:16:23.3 to look at how the two, the processes play out, right?

0:16:24.21 –> 0:16:25.93 In this thought experiment

0:16:25.93 –> 0:16:30.59 Or you can also do this in numerical, in the motto as well.

0:16:30.59 –> 0:16:35.59 You put a forest next to an open land

0:16:35.93 –> 0:16:40.15 and the two patches of landscape are influenced

0:16:40.15 –> 0:16:43.83 by same atmospheric conditions in terms of temperature,

0:16:43.83 –> 0:16:45.26 background temperature,

0:16:45.26 –> 0:16:49.29 in terms of incoming solar radiation, long wave radiation

0:16:49.29 –> 0:16:51.15 and so basically the value

0:16:51.15 –> 0:16:53.36 that those quantities are the same
across the two patches of land
at this order called a Blending height
which is typically taking its first mode
of great height about 50 meters
to a 100 meters above the surface right?
And then, so in this kind of site pair analysis
all a space for a time analysis that the contrast open land
the contrast in temperature which an open land
and the forest land is really your,
is really the deforestation signal
cause that’s how we approach this particular problem, right?
And so I don’t want to get into too much
of a mathematical details except to say,
this is how we frame the problem,
we combined what we call
the one source of a model for heat transfer,
surface energy balance conservation of energy at the surface
in this One source Model heat is dissipated
from the ground to Reference height
and using some kind of resistance analog right?
So the heat of efficiency of heat flux
is really proportional to temperature difference
between difference in temperature
between the surface and temperature at a lower atmosphere
at a per landing height.
So you combine those two sort of considerations.
You’ll come up with a solution for surface temperature
And then you do a sort of the perturbation to decide mathematically it’s just, that’s equivalent to differentiating this equation and so you then get perturbation signal. That’s your temp deforestation signal by replacing it four of this open land, you get a temperature change, that’s the temperature change mathematically and then the temperature changes then it’s partitioned into three components. The first component has to do with changing albedo. I mentioned earlier using that Israel example, the second component has to do is back. The energy redistribution efficiency has changed due to a change of reference. So forest landscape is very rough and very efficient in generating triplets, it’s very efficient in dissipating energy by triplets but open land, it’s very smooth so it’s not as efficient. So that itself will cause change in temperature and then the third component contribution is change of energy redistribution due to evaporation change or change of evaporation and that can go either way when you compare forest to open land depending a forest cover to open land depending on which one has higher evaporation potential. So that is the approach we use to study a deforestation and it later turns out that we have two prompters here, one is this local climate sensitivity prompter.
which is more or less constant
but this prompt F is energy redistribution factor. Some people have done quite a bit of work on this prompter and turns out this prompers more like a property of the landscape. So for example, this is a study by Bright et al looking at Energy redistribution factor for different ecosystem. This is evergreen needle-leaf forest, deciduous broad-leaf forest evergreen broad-leaf forest two types of crop lands, rain fat irrigated and this is grassland. Typically when you compare a forest versus the grass open land, you find the energy redistribution factor much high for forest especially for tropical evergreen broad-leaf forest meaning that they are a disturbance, just external sort of perturbation will not change his temperature as much same perturbation occurring over grassland because over or at this kind of landscape, the energy is can be dissipated very quickly to the atmosphere and therefore is more resistant to change in temperature,
and then later on TC from my lab did this calculation mapping the energy redistribution factor across the globe given the current distribution of vegetation types
of course and you find a high value in tropical places and low value elsewhere and then Nighttime value is much lower so there's, when you look at tables night contrast Daytime energy redistribution factors is much higher than at Nighttime meaning that same amount of changes of a disturbance would cause much higher response in temperature at nighttime than in the daytime. So that kind of day and night symmetry is also very important in the consideration of how land use change affects the surface temperature. So basically then we'd say okay well, let's just extend this to urban landscape right? You've sent the urban landscape now instead of contrasting for us was open ended. We are contrasting a natural land versus urban land. That's the urban heat Island signal right? And so you go through that little model you find then now you have five contributions one is changing the albedo or radiation convection effect, evaporation effect changing storage and change your anthropogenic heat. So a few years ago, my former student lays out, did this attribution analysis based on this model and then did a partitioning of urban heat island intensity to and partition the urban heat Island intensity to different factors.
and this is a very complex plot that maybe I should show you.

I tend to just read this particular diagram. This diagram is daytime urban heat island on in situation for four cities in East, Southeast United States including where we are and so this is sort of wet climate. So and this is the modis settling observed over here. He did in intensity, this a climate model calculate intensity. This is the summation of the in individual terms, individual contributions right? So in the case of cities, this part of the world actually Albedo effect is cooling contrary to what many people believe. This turns out cities in this part of the country our axe is brighter than the background, but then the rural background is mostly forests are dark. So the Albedo effect is cooling but so what's surprised us actually, this connection effect right? It turns out in this this kind of climate, this region urban land is not efficient in dissipating heat than the background forest land and so as a result of loss of convection efficiency you have an obviously a lot of warming. So it’s actually this loss efficiency dominates urban heat Island intensity,
0:24:15.66 –> 0:24:18.443 is much stronger than the effect
0:24:19.452 –> 0:24:22.102 of loss of evaporative cooling, right?
0:24:22.102 –> 0:24:25.17 So that’s the that kind of interpretation
0:24:27.156 –> 0:24:29.97 of the based on that model
0:24:29.97 –> 0:24:32.28 and so this kind of attribution.
0:24:32.28 –> 0:24:34.42 this kind of practitioner is obviously very important
0:24:34.42 –> 0:24:38.24 when you’ve tried to formulate a mitigation strategy
0:24:38.24 –> 0:24:39.97 whether you want to say for example,
0:24:39.97 –> 0:24:42.08 you want to change our Albedo or change
0:24:44.18 –> 0:24:45.38 in evaporating
0:24:47.7 –> 0:24:50.55 client trees by improving evaporation.
0:24:50.55 –> 0:24:52.75 So you can use this to help determine
0:24:52.75 –> 0:24:54.35 which one is more efficient
0:24:54.35 –> 0:24:58.65 whether Albedo of change or change of gray infrastruct-
0:24:58.65 –> 0:25:00.62 or tangible green infrastructure
0:25:00.62 –> 0:25:02.653 which one gives you more cooling power.
0:25:04.54 –> 0:25:07.73 And then so that study was done prior
0:25:09.564 –> 0:25:10.397 to Google earth engine
0:25:10.397 –> 0:25:15.003 not always before Google earth engine error.
0:25:17.339 –> 0:25:20.6 So we’ve hand picked a 60 some cities
0:25:20.6 –> 0:25:23.53 and we manually select a satellite data
0:25:23.53 –> 0:25:26.2 and that was a lot of work right?
0:25:28.29 –> 0:25:28.29 But now we Google Earth Engine
0:25:28.29 –> 0:25:32.29 the marking of Urban heat island much easier.
0:25:33.8 –> 0:25:33.8 I just want to draw your attention
0:25:33.8 –> 0:25:36.16 to the work done by TC again,
0:25:36.16 –> 0:25:39.11 he used the Google App Engine
0:25:39.11 –> 0:25:41.837 to map out basically the urban heat island
0:25:41.837 –> 0:25:44.253 for all the cities in the world.
0:25:45.252 –> 0:25:48.78 You can go to this link and you can pick any city.
I can then, there’s this interface allows you, this Explorer allows you to map out local urban heat Island and also variation of time change of urban heat island or the satellite air.

Now let me switch gear here and speak about mitigation right? Mitigation and we know urban heat Island is not a good thing, especially in hot weather conditions, it exacerbate the heat stress on our urban residents so we like to perhaps modified urban landscape to comeback, to control, to reduce the intensity of Urban heat island.

So this is a sort of a summary of the kind of strategies that people are considering right?

One strategy is white roof, you basically convert a dark roof to replace dark roof with some kind of a white shiny bright material to increase Albedo so you then cool the urban climate.

The other strategy is strategy promoted by the city of Chicago you know, putting green vegetation on rooftop like indicate this case is a City Hall and a third strategy is the one that our school used is to convert a rooftop to cover the rooftop with Solar Panel. The benefit there is that instead of allowing radiation to turn into heat, you actually capture solar radiation.
and convert some of it into electricity and therefore avoiding heating the local environment right? So that would also bring cooling benefits. It’s a fourth approach is to use Street trees to help cool whenever you can wherever you can plant trees to cool the local climate. So the question is which one is more effective, right? And if so how do you quantify that before I do give you a solid quantification, I just want to draw your attention to this case in Chicago. It turns out changing roof top albedo is not a theoretical concept, it’s actually been actively promoted in many cities, city of Chicago was one of the pioneer cities promoting this idea, promoting this approach using a brighter reflective materials to help cool the local climate to help control the local urban heat Island, this is a work done by a former student of professor Ron Smith and myself. So he quantified change in urban out Albedo in Chicago after 1995, after that notorious heat wave that kills a hundreds of people and turns out we can actually, we were able to quantify change of the citywide Albedo the city over this time period,
The city’s albedo has increased by a little bit, by 0.02. This is a homework exercise. I’ll ask my students to do when they do my class. And this isn’t in my book. Sort of homework exercise. You know the question asked is that, when the albedo is increased by this much, estimate how much temperature reduction you get, right? So you can basically go back to that model that I presented you earlier. But now the situation is much simpler, you don’t need to worry about changing energy redistribution because we have not changed urban form. We only did change the roof of albedo. So you have that single prompter problem. We all only did change the roof of Albedo. Only what we did was just to change the roof of Albedo. So you have that single prompter problem. If you put numbers together, you’ll find that the 0.02 change in albedo would cause a cooling on average of 1.5 degrees Celsius. That could be quite important in the event of a heat wave.

Now let me share with you the pertinent results. In the case of Chicago, that’s really a local example, and then we use climate models and in with fall, all kinds of scenarios. Climate scenarios also mitigation scenarios.
0:30:32 –> 0:30:34.69 using our partition efforts.
0:30:34.69 –> 0:30:35.523 So this is a...
0:30:35.523 –> 0:30:37.493 Let me help you interpret this diagram a little bit.
0:30:37.493 –> 0:30:42.493 This is the condition for Mid summer day
0:30:42.79 –> 0:30:45.66 for cities in the United States average condition
0:30:45.66 –> 0:30:47.69 of all the cities in the United States
0:30:47.69 –> 0:30:50.14 not also the 60 some cities in the United States.
0:30:50.98 –> 0:30:54.05 So this is, would be the current background temperature.
0:30:54.05 –> 0:30:54.883 You get
0:30:56.433 –> 0:30:57.3 on a hot summer,
0:30:57.3 –> 0:31:01.57 at summer noontime in rural background,
0:31:01.57 –> 0:31:02.403 okay?
0:31:02.403 –> 0:31:05.02 And this is then the urban temperatures here
0:31:05.02 –> 0:31:06.62 on the current climate condition
0:31:06.62 –> 0:31:09.76 in a future climate near the end of century,
0:31:09.76 –> 0:31:12.43 the rural background will be up here
0:31:12.43 –> 0:31:14.24 and urban temperature would be up here.
0:31:14.24 –> 0:31:15.81 So we will forever residents,
0:31:15.81 –> 0:31:20.39 we were gonna expect this much of a temperature, right?
0:31:20.39 –> 0:31:23.54 We referenced to current rural background
0:31:23.54 –> 0:31:27.46 and so by implementing core roofs
0:31:27.46 –> 0:31:28.78 we are, we stay in the model,
0:31:28.78 –> 0:31:33.78 we change all the roofs to core to highly reflective roofs.
0:31:34.11 –> 0:31:35.81 We get this much of cooling,
0:31:35.81 –> 0:31:38.2 that’s substacalling substantial right?
0:31:38.2 –> 0:31:42.77 Basically you raise all the urban heat Island effect
0:31:42.77 –> 0:31:45.65 and all some greenhouse effect
0:31:45.65 –> 0:31:48.42 and then we say, okay, let’s plant street trees,
0:31:48.42 –> 0:31:51.57 well, there’s only a limited space
0:31:51.57 –> 0:31:52.87 for planting street trees,
0:31:52.87 –> 0:31:57.87 but we planted street trees in the model anywhere we can
0:31:58.09 –> 0:32:00.72 and also we change reflect your pavements
0:32:00.72 –> 0:32:04.34 change your pavements to reflect your material.
0:32:04.34 –> 0:32:06.64 So this is what we call additive effects,
0:32:06.64 –> 0:32:11.64 it’s like the IBL from mitigation wedge, right?
0:32:11.75 –> 0:32:13.51 People talk about when we talk about dealing
0:32:13.51 –> 0:32:15.39 with greenhouse mitigation here,
0:32:15.39 –> 0:32:18.03 you can use the same idea of a wedge idea
0:32:18.03 –> 0:32:21.51 to see the attitude of strategies
0:32:22.997 –> 0:32:25.89 for mitigating urban heat Island.
0:32:25.89 –> 0:32:30.4 So in this is very aggressive scenario of course
0:32:30.4 –> 0:32:34.72 we can raise all the Urban heat island
0:32:34.72 –> 0:32:36.45 and greenhouse effect.
0:32:36.45 –> 0:32:39.28 We actually have some additional cooling
0:32:39.28 –> 0:32:41.78 of course, it’s highly idealized and real world,
0:32:41.78 –> 0:32:44.79 we cannot achieve this maximum cooling
0:32:45.87 –> 0:32:48.23 but it’s instructive to show that indeed
0:32:48.23 –> 0:32:52.57 a core roof Australia is much more effective
0:32:52.57 –> 0:32:56.353 than street tree or reflect your payment.
0:32:58.82 –> 0:33:01.57 So spatially, this is what this looks lik, right?
0:33:01.57 –> 0:33:02.69 If you don’t do
0:33:05.627 –> 0:33:08.5 any change to the urban landscape at the end of the century
0:33:08.5 –> 0:33:11.083 you will still have a lot of urban heat Island.
0:33:11.083 –> 0:33:12.823 This is circle,
0:33:14.09 –> 0:33:15.02 warm color circles
0:33:15.02 –> 0:33:16.63 indicate Urban heat island.
0:33:16.63 –> 0:33:20.93 We have a few cities that actually have cool like Island
0:33:21.99 –> 0:33:24.943 indicated by the cold color,
but they never that’s on average, you’ve got quite strong urban heat Island
but if you use EPA white roof everywhere in this cities, you actually now have a cold Island almost across the whole country.
This is of course in a Daytime situation but the white roof does not work as well for nighttime obviously, right?
White roof works because it reflects sunlight in the daytime but at nighttime there’s no sunlight took to stick off so you don’t get much of a benefit at nighttime.
So that still would be still is an important hurdle to overcome how do you call a nighttime temperature?
The white roof would not be an effective approach for that.
So that the calculation is done really theoretical right, in the theoretical calculation and we don’t really get a sense of the kind of change we are calling for, the change Urban land form is really substantial.
If you really want to follow this strategy I’ll be implementing white roof everywhere. So for that we decided to well the triplets, do some visualization.
This visualization is based on a data source sort of drawn data collected by this company over a neighborhood in a city in, I think in Switzerland.
and so we then use this to perform some animation. Let me see if I can turn the animation over here. It does not, let me see way by control here. (indistinct) Okay there it’s going. So this is the current landscape, right? We’re doing a fly by as if we were a bird looking at the landscape from different angles. It’s a very pleasant landscape, have a dark roof green lawn and street trees and then we say, okay well, we’d like to change this landscape because we are very concerned about urban heat Island. So we then, we can artificially digitally alter the roof material to a white shiny high albedo material and then we’d do a fly by, right? So that, this is kind of landscape we are, we’ll be looking at if we do implement that white roof strategy it’s this very alien landscape, we are not very used to, a lot of people criticize us for saying that because they said, this is not a pleasant landscape to a city to be in and pass maybe you wouldn’t be detrimental to pilots because they can’t see the ground well and maybe they will get blinded by the Brighton yourself
0:37:14.841 –> 0:37:16.07 the roof.
0:37:16.07 –> 0:37:20.92 But anyway, so that’s obviously a big change we need,
0:37:20.92 –> 0:37:23.27 we will be expecting
0:37:23.27 –> 0:37:25.22 but now let me switch gear a little bit
0:37:26.533 –> 0:37:28.04 to what we are doing now.
0:37:28.04 –> 0:37:30.04 So I won’t pick a criticism
0:37:30.04 –> 0:37:32.63 of the work we have been doing is that
0:37:32.63 –> 0:37:34.26 we are using surface temperature
0:37:34.26 –> 0:37:36.8 as a measure of heat stress,
0:37:36.8 –> 0:37:38.98 temperature at the surface of landscape
0:37:38.98 –> 0:37:43.98 but people obviously, this is obviously is not accurate
0:37:44.05 –> 0:37:46.6 because to measure heat stress,
0:37:46.6 –> 0:37:48.76 you need to use air temperature
0:37:48.76 –> 0:37:52.47 and furthermore heat stress is not only caused
0:37:52.47 –> 0:37:56.27 by temperature, it’s also caused by high humidity.
0:37:56.27 –> 0:38:01.01 we should be using some kind of combined index,
0:38:01.01 –> 0:38:03.35 index that can combine both air temperature,
0:38:03.35 –> 0:38:05.51 not surface temperature but air temperature
0:38:05.51 –> 0:38:06.56 and also air humidity
0:38:08.67 –> 0:38:12.03 so that a perspective from the thermodynamic person,
0:38:12.03 –> 0:38:15.11 turns out the best way of measuring the combined effect
0:38:15.11 –> 0:38:17.213 is to use one called Wet-bulb temperature,
0:38:18.258 –> 0:38:19.28 in meteorology,
0:38:19.28 –> 0:38:21.64 this is how we measure Wet-bulb temperature, right?
0:38:21.64 –> 0:38:25.35 So we cover the thermometer with some kind of Wet cloth
0:38:25.35 –> 0:38:27.44 allowing the surface of the thermometer
0:38:27.44 –> 0:38:29.05 to be wet all the time
0:38:29.05 –> 0:38:33.709 and so, and allow the evaporation to occur at the surface
and so the temperature you imagine that this situation is Wet-bulb temperature and so that’s a thermodynamic parameter that meteorologists use a lot to characterize the thermal environment. It turns out though in a hot environment sweating is obviously is a way, it’s the only way actually for us to maintain low skin temperature, a person who is sweating a lot can be considered essentially a big wet bulb cause we assume the body is exposed, no clothing and the whole body is covered with sweat so analogous to a wet bulb. So then you can use wet bulb temperature to see the effect of heat stress on human body just to survive hard environment we need to maintain a two degree difference between skin and a deep body temperature so that our body can dissipate heat to the environment right? But then it turns out if the We-bulb temperature of the environment goes beyond 35 degrees, this is no longer possible, we wouldn’t be able to be able to maintain a two degree difference. Our skin temperature would be higher than 35 degrees and if we don’t have air conditioning. So without air conditioning we cannot survive
when external environmental temperature or Wet-bulb temperature goes beyond 35 degrees. That’s really the physiological barrier the limit that you know, determines the survivability or habitability of the law of the environment. So we are knowledge high trying to come up with a strategy of studying using a wet bulb instead of the surface temperature to quantity that’s undergoing a new project, it’s a collaborative project happening here at Yale, it’s called Biking for Science and Health and so the idea is that we can use bicycles to help out map out temperature and humidity across urban and rural landscape and use that as a way of collecting data to validate a model calculation of course the project oe the objective of this project is much broader than only measuring temperature. So the broad objective is to integrate smart sensor technology with public bicycles or maybe private bicycles as well for urban environmental monitoring so T-Mobile for scientists including professor Dubrow as part of the team and so this is that the idea right? So we, what we want to do is to convert bicycles into measurement platform either volunteer cyclist bicycles,
planning to volunteer cyclist or public bicycles.
So and then, the smart sensor
would sense the environmental conditions
temperature humidity and in the future,
we also want to measure air pollutants
and so the sense of what, then you turn a cyclist smartphone
into some kind of geolocation
data collection device and that data can then try
to transmitted to some kind of a server to allow
in the case of public bicycles
the data will be automatically transmitted to a data server,
and then the data server
would then dispatch data to different users
and so that’s the idea.
So we are having some success
in terms of designing a sensor,
a smart sensor for temperature humidity.
This is a patch of smart temperature humidity sensors,
very small and this is a picture
of all this smart sensors
against commercial sensors right?
and calibrate it against commercial sensors right?
This is, oh sorry.
Before I share with you some data,
this is the kind of sensor right?
It’s very small
or this is the interface, smartphone interface
and this is to give you a scale of the sensor,
a cache to the bicycle handlebar
0:42:57.6 –> 0:42:59.78 and so I’ll show you that the idea we have
0:42:59.78 –> 0:43:01.738 is to recruit volunteer cyclists
0:43:01.738 –> 0:43:04.77 and eventually we can also implement sensors
0:43:05.972 –> 0:43:07.13 on public bicycles
0:43:07.13 –> 0:43:08.7 but in case of volunteer cyclists
0:43:08.7 –> 0:43:09.533 we are hoping,
0:43:09.533 –> 0:43:12.03 we are defining sort of kind of data interface.
0:43:12.03 –> 0:43:15.95 This is work by TC and Yichen interface
0:43:15.95 –> 0:43:18.81 to so that when the data is sent
0:43:18.81 –> 0:43:21.543 to some kind of data center,
0:43:21.543 –> 0:43:25.97 the cyclist would receive a link.
0:43:25.97 –> 0:43:30.03 The link then allows the cyclist to view the bicycle route
0:43:30.03 –> 0:43:33.78 as well as the conditions, temperature condition
0:43:33.78 –> 0:43:35.73 and humidity and maybe in the future
0:43:35.73 –> 0:43:40.73 also air quality parameters and along the route by spiked
0:43:40.89 –> 0:43:42.75 we are still having trouble with the color scale yet
0:43:42.75 –> 0:43:44.974 but if this is the kind of general idea, right?
0:43:44.974 –> 0:43:48.37 And so you can actually look at data, put the data
0:43:48.37 –> 0:43:52.48 this kind of spaghetti plot under different map back-ground.
0:43:52.48 –> 0:43:54.99 This is just pure simple map background.
0:43:54.99 –> 0:43:56.8 You can put it in a,
0:43:56.8 –> 0:43:59.44 you know, satellite background map background
0:43:59.44 –> 0:44:03.02 or you can put down in street map background.
0:44:03.02 –> 0:44:07.42 So this is not place still very much a work in progress.
0:44:07.42 –> 0:44:10.63 So I was up here and see if we have questions.
0:44:10.63 –> 0:44:13.723 I like leave some time to engage.
0:44:13.723 –> 0:44:17.36 I was discussion and questions.
0:44:17.36 –> 0:44:18.36 Thank you very much.
0:44:19.68 –> 0:44:24.57 - Thank you, (indistinct) for the wonderful presentation.
0:44:24.57 –> 0:44:28.68 We do have a lot of questions from the students.
0:44:28.68 –> 0:44:31.49 But if people,
0:44:31.49 –> 0:44:33.61 if you have your own questions
0:44:33.61 –> 0:44:37.55 please type your question in the chat box while
0:44:39.15 –> 0:44:42.3 Dr. Lee was answering to the students’ questions.
0:44:42.3 –> 0:44:44.34 So the first question actually
0:44:45.51 –> 0:44:48.45 don’t be you showed a very very interesting
0:44:48.45 –> 0:44:52.68 with us about them, why the core roofs
0:44:52.68 –> 0:44:54.24 and I had receive a lot
0:44:54.24 –> 0:44:59.24 of question from the students asking about the comparison
0:44:59.47 –> 0:45:03.55 between a white roof versus a green roof.
0:45:03.55 –> 0:45:07.822 They were particular interesting in whether,
0:45:07.822 –> 0:45:11.37 what do you think about like the disadvantage
0:45:11.37 –> 0:45:15.183 of the white roof compared to the green roof?
0:45:16.08 –> 0:45:18.653 - So my White roof is not very pleasant, right?
0:45:18.653 –> 0:45:21.147 You don’t like that in your neighborhood
0:45:21.147 –> 0:45:25 and if I showed you with that, a drone sort of animation
0:45:25 –> 0:45:28.47 the landscape’s not that pleasant to look at
0:45:28.47 –> 0:45:31.36 but in terms of cooling this surface climate,
0:45:31.36 –> 0:45:33.74 white roof is much much more effective than green roof.
0:45:33.74 –> 0:45:36.613 I’ll tell you why, in green roof, you have to,
0:45:38.433 –> 0:45:40.9 first of all, it’s very difficult to plant trees
0:45:40.9 –> 0:45:42.993 on a roof right?
0:45:43.958 –> 0:45:47.46 So trees tend to sustain evaporation much more
0:45:48.879 –> 0:45:50.36 than grass than shrubs
0:45:50.36 –> 0:45:52.74 and so, but if you just planted shrubs
0:45:52.74 –> 0:45:57.057 and grass on rooftop, you have to constantly irrigate them
0:45:58 –> 0:45:59.857 in order to get cooling benefit
and then your irrigation is not easy especially if you have a tall buildings and think about pumping water up to the rooftop and irrigate right? So that’s itself is a very energy intensive endeavor. So absence of the radiation green roof really won’t do much to the local temperature but I should have knowledge of obviously green roof is much more pleasant right? It’s maybe has other benefits beyond just cooling the local landscape. So that’s a debate obviously that’s people should, that aspect should be considered when you look at a white roof versus a green roof. So if you look at the cooling power street vegetation is more effective than green roof. So you’ve put green roof here, the effect is really tiny compared to a quarrel for white. Thanks, I think we will get more questions on these from the audience, but I will move on to the other question from the students. The other questions students are wondering is like you introduce us about the concept of urban heat Island and students are wondering like a lot of the mitigations we take for the urban area that’s that has also impact for the adjacent rural areas. Like if we do all these, why move
0:47:34.2 –> 0:47:35.74 in urban area,
0:47:35.74 –> 0:47:38.23 does it also like
0:47:38.23 –> 0:47:40.31 simultaneously reduce
0:47:41.31 –> 0:47:43.683 the heat exposure in the rural area?
0:47:44.66 –> 0:47:46.12 - Yeah, that’s a very good question.
0:47:46.12 –> 0:47:49.69 I think, so that really the question maybe can be brought
0:47:49.69 –> 0:47:53.74 in a little bit to say that’s changing urban forms
0:47:55 –> 0:47:57.07 whatever way does the have effect
0:47:57.07 –> 0:47:59.72 on regional climate or even global climate?
0:47:59.72 –> 0:48:00.56 Right?
0:48:00.56 –> 0:48:02.42 The answer is probably no,
0:48:02.42 –> 0:48:06.67 because we are we are talking about change,
0:48:06.67 –> 0:48:08.22 intensive changes that’s
0:48:08.22 –> 0:48:11.127 but the intensive change,
0:48:11.127 –> 0:48:16.127 is only occurs in a very tiny fraction of the landscape.
0:48:16.57 –> 0:48:20.55 Urban land is what 2% of the whole terrestrial land surface
0:48:20.55 –> 0:48:25.036 and so, and in that we have intensive modification
0:48:25.036 –> 0:48:27.64 that intensive modification will manifest itself
0:48:28.899 –> 0:48:32.88 in localized response but outside of urban area
0:48:32.88 –> 0:48:36.123 that the benefit is really really not that bad.
0:48:38.07 –> 0:48:39.863 So the answer is probably, no,
0:48:41.57 –> 0:48:45.5 unless we are dealing with like a huge metropolitan region
0:48:45.5 –> 0:48:50 maybe in India, where you have clusters of cities,
0:48:50 –> 0:48:52.18 a lot of cities cluster together
0:48:52.18 –> 0:48:54.74 maybe then there, you might have some effect
0:48:54.74 –> 0:48:56.333 on background temperature.
0:48:58.77 –> 0:49:00.83 - Thanks, I think, yeah.
0:49:00.83 –> 0:49:03.2 I think if we got a follow up customer
0:49:03.2 –> 0:49:05.11 regarding the green roofs

32
so they were asking one of your paper, The Jaw and The Shoes article, in that paper, there’s mixed implementation of the white and green roofs and the given the green roofs lead to increase the evaporation and likely increase humidity with wide roofs and green roofs have under donor’s state effects due to green roofs contributing to the Web-bulb temperature - Yeah, yeah, that’s an excellent point and so if you take that humidity into consideration you probably don’t actually, you want to avoid a green roof because green roof on one hand you will reduce the air temperature. but on the other hand, it will increase humidity, right? So the reduction air temperature could be totally erased or the effect of temperature reduction could totally raise by enhanced humidity factors. And so, and of course in this analysis, the solid dollar analysis we have not brought in the concept of wet bulb, but if we bring wet bulb into consideration that may be an argument we should consider seriously. Yeah, I’ll also from the audience a question regarding the implementing of the core roof policy, have you considered whether you paint all the roofs white
0:50:38.14 –> 0:50:41.367 or use how they are scattered
0:50:41.367 –> 0:50:43.71 painting within the city?
0:50:43.71 –> 0:50:47.77 So do you consider the difference of the painting
0:50:47.77 –> 0:50:52.27 depend all the buildings, all you does a scattered be-
cause.
0:50:52.27 –> 0:50:57.27 - So in this calculation, we except hypothetical calcu-
lation
0:50:57.37 –> 0:51:02.37 we just combine all the routes to a high Albedo mate-
rial,
0:51:03.4 –> 0:51:06.41 in actual implementation I think you cannot do that
0:51:06.41 –> 0:51:08.98 because there’s no point actually doing
0:51:08.98 –> 0:51:10.47 a one size fits all situation
0:51:10.47 –> 0:51:12.97 because if you have North facing roofs right,
0:51:12.97 –> 0:51:17.42 then the deflections doesn’t doesn’t matter as much
0:51:18.35 –> 0:51:20.38 So maybe you need to differentiate North facing
0:51:20.38 –> 0:51:21.94 versus South facing roofs.
0:51:21.94 –> 0:51:23 In the city of Chicago,
0:51:23 –> 0:51:25.67 they actually have grades,
0:51:25.67 –> 0:51:28.06 if you have very steep roof, they ask you,
0:51:28.06 –> 0:51:30.6 they recommend certain kind of Albedo values
0:51:30.6 –> 0:51:33.23 when you have less steep roofs,
0:51:33.23 –> 0:51:34.72 they recommend other kind Albedo
0:51:34.72 –> 0:51:35.583 so he said,
0:51:38.381 –> 0:51:39.531 it’s mixed of strategy.
0:51:42.04 –> 0:51:43.72 By now all lot of cities actually
0:51:43.72 –> 0:51:45.96 aggressively promoting spokes,
0:51:45.96 –> 0:51:48.403 those kinds of reflect humid roof materials.
0:51:50.23 –> 0:51:52.68 - Thanks, I guess the audience
0:51:52.68 –> 0:51:55.46 and the students are very interested in this topic
though.
0:51:55.46 –> 0:51:57.767 They have accurately both the students
0:51:57.767 –> 0:52:00.53 and audience ask a question regarding
0:52:00.53 –> 0:52:02.02 have you ever considered
0:52:02.02 –> 0:52:05.29 all these heat Island mitigation matters?
0:52:05.29 –> 0:52:08.84 They may have some side effects on the air quality
0:52:08.84 –> 0:52:10.68 so how you
0:52:11.55 –> 0:52:13.663 kissing that in your own modeling?
0:52:14.75 –> 0:52:16.42 - Yeah, there’s a...
0:52:17.31 –> 0:52:21.1 So people say maybe for white roof material implementation
0:52:21.1 –> 0:52:22.84 it’s best to it in clean cities
0:52:22.84 –> 0:52:26.6 where there’s no, air quality is not a big concern
0:52:26.6 –> 0:52:31.15 in progic cities When you put in a white roof,
0:52:31.15 –> 0:52:32.5 you can change
0:52:33.67 –> 0:52:37.26 the way that the structure of the boundary layer
0:52:37.26 –> 0:52:39.87 essentially what happens is if you have a white roof
0:52:39.87 –> 0:52:43.93 you are not heating the low atmosphere as much.
0:52:43.93 –> 0:52:45.96 You’re reflecting a lot of sunlight away
0:52:45.96 –> 0:52:47.147 without us to the upper atmosphere
0:52:47.147 –> 0:52:49.15 and to the outer space, right?
0:52:49.15 –> 0:52:50.84 So what happens then is you end up
0:52:50.84 –> 0:52:53.81 with a shallow a boundary layer
0:52:53.81 –> 0:52:57.38 but there’s less mixing power, less mixing volumes,
0:52:57.38 –> 0:53:00.69 so you end up with higher air pollution concentration.
0:53:00.69 –> 0:53:03.65 So that’s the, it could be a serious societal effect
0:53:03.65 –> 0:53:05.49 especially imploded seedlings.
0:53:05.49 –> 0:53:06.973 So that’s another,
0:53:10.822 –> 0:53:12.922 this the harm you could say perhaps caused
0:53:14.484 –> 0:53:16.05 by air quality.
0:53:16.05 –> 0:53:17.3 That’s a very good point.
0:53:19.46 –> 0:53:24.46 - Thanks, another aspect of the students are wondering
0:53:24.58 –> 0:53:27.556 is like you showed a little bit about
the different like riddles from the satellite,
from the modeling and the students are particularly interesting in wanting these kind of modeling.
So how can you actually simulate the interactions with the global warming and also all the biophysical drivers of the urban heat Island in the continent models?
Okay, so in the climate models right, a lot of models don’t actually have what we call a city landscape that so, the model we use have what we call subgrid parameterization, so within each Greek cell you have different parches for that type of land so some great cells were contained urban land tile, urban tile and some would have no, if there’s no urban. So this model actually can calculate within which is great cell, temperature, humidity, and so on within for each tile. So typically when you download a data though, the data is aggregate to the Greek cell that was so you don’t see subgrade kind of a pattern. You don’t see a subgrade pattern but we are able to re redo the calculation and retrieve data within each Greek Model grade data for vegetations tile and offer urban tile. So that essentially set up the problem
for us to have to do then compare those subgrade tile data to get the urban heat Island calc apart from the climate models. That’s how a client model handles landscape heterogeneity within a model grid cell. Thanks, I think due to the time limitation, final question is the students and audience are very interested that what’s your recommendations for our daily life in as an individual, is it more eco-friendly to have solar panels or have a quarter of a solar. Solar panels are very interesting, right? You need to do a very sort of a careful calculation, to look at the benefits. So solar panel dependent if it’s true false for why is that you, like I said you convert a local solar radiation to electricity and in doing so, you don’t heat the environment, you don’t allow radiation to heat the environment but the commercial efficiency is not very high. It’s not as high as reflection by core roof. So on its own, you would say the cooling benefit of solar panel is not as high as core roof, but then you have an added benefit of electricity generated by solar energy right? So you offset the demand for fossil fuel energy.
So that benefits more broad modular views is you’re offsetting energy demand for fossil fuel and therefore you cool the whole club global climate. So there’s that, there’s a benefit to that so that you need to consider both sides local Coolig versus global cooling versus and offsetting energy and so that’d be a hard subject that need to be debated, right? But I think if you are, if you want to conserve your electricity bill, if you want to reduce your electricity bill in your house that you’re, the best approach is actually having a core roof. If you have at a core roof on your rooftop, then the demand for AC will be substantially reduced. You will have a lot of electricity saving in that way. That’s has to be demonstrated by a lot of people actually One fourth session. Thank you for all the insightful discussion and also the presentation and with that, I think we thanked Dr. Lee for this wonderful presentation and I thank you all for coming for our seminar. - Bye - See you guys.