Okay, welcome everyone to the Yale Center of Climate Change and Health seminar series. I'm Dr Kai Chen, assistant professor at the Yale School of Public Health and also the Yale Center on Climate Change and Health. So this is my great pleasure today to introduce our today's speaker Professor Michelle Bell. Professor Bell is the Mary E Pinchot Health Professor of Environmental Health at the Yale School of Environment. She's a recipient of many awards, including the Rosenblith New Investigator Award from the Health Effect Institute, the NIH Outstanding New Environmental Scientists Award the ONES award. Last year she was selected to the National Academy of Medicine. And I think there's no better coating for introduce her work from the National Academy for her global latest in environmental health addressing critical topics such as air pollution and climate change, and introducing large-scale models that have advanced environment research at both global and local levels.
So without further ado, I would turn the microphone to Michelle.

Great, thank you for that kind introduction Kai.

I’m gonna share my screen and if someone could give me a thumbs up to let me know if it works in presentation mode.

Went to the bottom of the presentation for some reason.

Is it working?

Yes, it works.

Okay, great, thank you.

So thank you so much for spending some of your day with me here to let me share my work.

I’m very excited to share this research with you.

And I want to thank Professor Chan and Professor Dubrow for this invitation.

I also wanna let you know I’m suffering from major COVID vaccine side effects.

So, just be kind with me today (laughing),

but I’m very happy to be here.

So I’m gonna talk about some work we’ve done on wildfires,

air pollution and health with a special emphasis on climate.

given the the sponsor of this seminar.

And this is an outline of the talk I’ve prepared for you today.

I’m gonna give some general background on wildfires,
I wanna share with you some research studies that we have conducted looking at how air pollutions, or smoke from wildfires can impact human health, and some of the work we’ve done in the context of climate change as well. I wanna briefly share with you some ongoing and planned research and then I’ll have a few concluding thoughts. So let me start with some background. So this is a slide that I’ve had for many years. I update it every year just to show the number of peer reviewed journal articles on climate change in health. And you can see this just incredible growth. This is updated through 2020, where we have this incredibly strong scientific interest in climate change in health. And I would argue a public interest and perhaps, political interest as well. If we look at the major laws and regulations worldwide for the environment, not all of them but most of them relate to human health. And human health has been missing from much of the climate change debate. And so I think that this is actually really critically important in that...
This Yale Center that Kai and Rob run is really critical to advancing that effort. This is a figure, it’s a bit complicated. I’m gonna walk you through parts of it but this is from a recent review article that we published. I’m gonna talk more about this article in a minute but we talk about the links between climate change, wildfire smoke and health. And my point for this figure is just to show that there are so many different pathways through which climate change could impact wildfires. It’s not just that there’s an overall warming. And so are you able to see my cursor maybe? Well, if you look in the upper right-hand side under climate change, you’ll see there’s high temperatures possibly lightening making a role, changes in precipitation, changes in wind patterns and so on. And then you see greenhouse gas emissions is combustion of fossil fuels leading down to impacts on human health. So my key point here being that there are a lot of really complex pathways through which climate change could impact wildfires, could impact human health.
And this is from an article that not one of my articles, another researcher’s article showing an increased in forest fires in the Western United States. And I wanna draw your attention to that lower figure with the red dots. And that’s showing from 1984 to 2017 this enormous change in wildfires, this is area burn. So this is not the smoke. This is the fire. I also wanna point out these kind of cyclical up and down, how we have this variation that goes up but in this zigzag pattern. This makes it very easy for someone either innocently or intentionally to downgrade or downplay the role that climate change has on wildfires. If they just pick off two or three points from this and there it looks like it’s going down or not increasing. And I thought it might be useful today to take a step back to what I was thinking when I first started looking at wildfires and human health several years ago. And so I just was interested in this topic and started reading some publications from the United States government. And I just wanna point out two of them.
One is from the US Forest Service, which noted that forest fire smoke was hazardous to human health. Even though there really has not been very many studies at the time, but they felt the US FS felt that given the overwhelming strong evidence that particulate matter from other sources is harmful to human health, we really should think that wildfire smoke is harmful to human health as well.

And then I saw lots and lots of economic damages associated from wildfires. And I’m just pulling out one example here.

So this is from NOAA, a US government agency and they estimated almost $7 billion in property damage and $58 million in crop damage over that period of about a decade. What’s really interesting to me was part of why I got studied in this research is none of the estimates I found at that time considered human health.

It’s like nobody coughed, right? So my argument is that the damages from wildfires are grossly underestimated because they’re not incorporating this change in human health. And that we had compelling evidence
that wildfire smoke harms human health, but there’s really a lot of uncertainty. And just wanna give a little more background about particulate matter. So particularly matter is the primary air pollutant we’re concerned about. I just wanna give some background. I think many people on this seminar will know a lot about particulate matter, but in case you’re not familiar maybe you work in water. It’s particles in the air that can be made up of different chemical composition, they can have different sizes and different shapes. And then really the size matters a lot. So this is a schematic from EPA showing the width of a human hair and then showing how small these particles can be. I wanna draw your attention to what’s (indistinct) the pink particles. Of course, they’re not pink. but in this figure of the pink particles showing that the PM 2.5 particles from combustion are very, very small. They penetrate deeper into the respiratory system than do larger particles.
And this is what we’re having from combustion from wildfires.
Okay, I wanna go back to this review article that we published recently in "New England Journal of Medicine,"

And so this is an article that’s a review article that gives some kind of synthesis of what do we know about wildfires, global climate change and human health.
I have a slide on some of our references at the end of this, if you’re interested.
So if you wanna know more about this topic and wanna read one article or small number of articles this might be one you wanna check out.
And I wanna highlight that we went through and looked at the characteristics and health risks of wildfires.
Like what’s the state of the science.
So let me blow up part of our table.
So for mortality, we concluded there was consistent evidence.
Those of you who have taken my class know that I and other people in public health are very cautious about using words like cause or proven or things like that.
So we use a lot of this couched language, consistent evidence but that should by no means be considered that we don’t have very strong evidence. It's just scientists being really careful. So we have consistent evidence that there’s an increase in mortality from wildfire smoke and a real critical question is, are the particles from wildfire more or less harmful than particles from other sources? This is a broader question where we could look at particles from vehicles versus particles from coal combustion versus all combustion versus agriculture and now versus wildfires. And the evidence on this it’s not perfectly consistent. So we said that for mortality wildfire particles may have a stronger effect. Now why would different sources have different impacts? Well, as I mentioned, the particles have different sizes but they also have different chemical compositions. So if you have a particle that’s coming a lot from oil combustion it’s gonna have a lot of nicken vanadium. If it’s coming from coal combustion,
226 00:09:34.960 --> 00:09:37.460 it's gonna have a lot of ammonium sulfate and so on.
227 00:09:37.460 --> 00:09:39.740 So different particles have different chemical structures.
228 00:09:39.740 --> 00:09:42.320 And we know these chemical structures matter
229 00:09:42.320 --> 00:09:43.500 for human health impacts.
230 00:09:43.500 --> 00:09:45.880 Although none of the particles are good for you.
231 00:09:45.880 --> 00:09:48.910 So this is why this is a critical question.
232 00:09:48.910 --> 00:09:52.700 We concluded consistent evidence of respiratory impacts
233 00:09:52.700 --> 00:09:57.050 maybe a stronger effect on asthma related events.
234 00:09:57.050 --> 00:10:02.240 So the basic summary of this table
235 00:09:59.170 --> 00:10:02.240 and my wording would be that we have very strong evidence
236 00:10:02.240 --> 00:10:03.610 that there is something happening
237 00:10:03.610 --> 00:10:05.820 for wildfire smoke harming human health,
238 00:10:05.820 --> 00:10:07.680 but there are a lot of unanswered questions
239 00:10:07.680 --> 00:10:10.810 that we could continue to investigate as well.
240 00:10:10.810 --> 00:10:12.850 So for example, the long-term health effects
241 00:10:12.850 --> 00:10:15.650 I’ve highlighted here we said they were largely unknown.
242 00:10:16.890 --> 00:10:19.510 So let me move to the second part of this talk
243 00:10:19.510 --> 00:10:21.778 where I really wanna highlight some of the research studies
244 00:10:21.778 --> 00:10:25.233 that my team has done looking at wildfire smoke.
245 00:10:26.160 --> 00:10:28.380 I wanna highlight my two key collaborators
246 00:10:28.380 --> 00:10:29.213 for this project.
247 00:10:29.213 --> 00:10:32.010 They’re both at Harvard University, Francesca Dominici
248 00:10:32.010 --> 00:10:34.480 who’s a biostatistician and Loretta Mickley
249 00:10:34.480 --> 00:10:37.410 who is a wildfire modeler amongst other things,
250 00:10:37.410 --> 00:10:39.500 amongst other types of air quality modeling.
251 00:10:39.500 --> 00:10:41.470 So I know there’s a lot in this slide
252 00:10:41.470 --> 00:10:43.210 but let me just through some key features.
253 00:10:43.210 --> 00:10:45.800 So the first upper left,
254 00:10:45.800 --> 00:10:47.900 we started with forest fire emissions.
255 00:10:47.900 --> 00:10:49.640 And by we, this is Loretta Mickley
256 00:10:49.640 --> 00:10:52.160 who’s an expert in this, and we have informa-
257 00:10:52.160 --> 00:10:54.590 on forest fires, on anthropogenic emissions,
258 00:10:54.590 --> 00:10:57.490 meteorological data we’re using the GEOS-
Chem model.
259 00:10:57.490 --> 00:10:58.760 And then as you move to the right,
260 00:10:58.760 --> 00:11:00.000 I don’t know if you can see my cursor
261 00:11:00.000 --> 00:11:02.395 but these two orange blocks in the upper right.
262 00:11:02.395 --> 00:11:04.050 We have daily estimates of PM 2.5
263 00:11:04.955 --> 00:11:09.670 from all sources and from wildfire and from non fires.
264 00:11:09.670 --> 00:11:12.210 And then we can estimate the PM 2.5
265 00:11:12.210 --> 00:11:14.610 from wildfires specifically,
266 00:11:14.610 --> 00:11:17.040 This is an enormous advancement over
267 00:11:17.040 --> 00:11:19.410 some of the previous studies that look at satellite imagery
268 00:11:19.410 --> 00:11:21.203 and so on to really look at,
269 00:11:22.270 --> 00:11:25.440 does there appear to be a wildfire here, yes, no.
270 00:11:25.440 --> 00:11:27.290 Here we’re actually estimating
271 00:11:27.290 --> 00:11:29.570 the actual level of wildfire pollution.
272 00:11:29.570 --> 00:11:31.960 And we’re able to distinguish between parti-
273 00:11:31.960 --> 00:11:34.870cles from wildfires and particles that aren’t.
In the second aim, we're linking these estimates to Medicare data for the United States or for urban areas in the United States, trying to see if these wildfire smoke is associated with increase in hospitalizations and I'll show you some results later. And then in the third aim, we wanna look at what wildfires might look like under a changing climate. So in my talks, I like to give you a little peek behind the curtain of what’s happening in the research. Sometimes I just don’t like when I do this, you're giving away our secrets, but let me tell you some things that happened for wildfire smoke. When I first started working on wildfires, the wildfire modelers, including Loretta Mickley and others kept talking about the validation of their model. This is what they were talking about is area burned, right? The models did very, very well for area burned, but I wasn’t interested area burned. I’m interested in this. So this is something really important for climate change and while we need interdisciplinary research,
it’s not good enough to just say my model was validated,
validated for what?
Validated to accurately estimate area burned,
doesn’t mean you’re getting accurate estimates of smoke
thousands of kilometers away.
Alright, Loretta Mickley who’s my favorite wildfire modler,
one of my favorites.
She got this very, very quickly.
And so she went and did some validation
of the wildfire smoke and we found
that the models work well for that too.
Next, I wanna highlight some of the research we’ve done
looking at wildfire PM 2.5.
So these are small particles fine particles in health.
In the photo there is a one of
the lead researchers for this work.
She’s a former PhD student Coco Liu.
And so in this research, we had several challenges
and I wanna highlight two of the key challenges
to give you again a little peek behind the curtain.
The first one is we really were interested
in estimating wildfire smoke, the PM 2.5 from wildfires
not just PM 2.5 during a wildfire.
And we use that with our wildfire modeling and GEOS-Chem.
The second challenge is one that we didn’t really anticipate is that the day-to-day structure of how wildfire smoke varies in concentration is very different from other pollutants. So you can think of ozone is kind of low, it’s high in summer, and it comes back down or it has a diurnal pattern and particles kind of do like this. Wildfires it’s radically different. It’s nothing, nothing, nothing, nothing, nothing crazy high.

So the traditional air pollution by statistical models to look at air pollution didn’t function as well. So what we did and actually Coco came up with this new concept called a smoke weight. It’s really analogous to a heat wave. So it’s a series of contiguous days that have a high level of PM 2.5 specifically from wildfires. And we use this to characterize wildfire pollution episodes and compare the risk of different health events during that episode to non wildfire episodes that were not right up against that wildfire episode. So we used a variety of different definitions to categorize the smoke wave.
but you could really think of it too similar to a heat wave
where you might have a heat wave defined as two or more consecutive days with temperature
over the 95th percentile, or you could have three
or you could have three
or you could use the 96 percentile and so on.
So here’s some of our results
were published a few years ago.
For this particular result I’m showing you it’s a smoke web definition of two or more days
with wildfire specific PM 2.5 greater than 37.
That should be microgram per cubic meter.
That’s a typo, I’ll fix it later, my apologies.
And so what we’ve found or Coco’s paper is that there was
over 7% increase in respiratory hospital admissions
for people 65 and older in the United States.
Let’s just the Western United States
during smoke waves compared to non-smoker wave events.
I wanna highlight another point here
about epidemiological public health research.
Sometimes when I’m talking to decision makers
and people in Congress and so on,
7% might seem like a big number to them
or it might seem like a small number to them.
And my students know that I caution us
against using words like only 72.2% or trying to make the number sounded bigger, sound small.

I prefer to let the numbers speak for themselves.

I do wanna point out that this number, the 7.2% increase is on everybody exposed to the event.

So a 7% increase that only affected 100 people might have one public health burden,

but a 7% increase that affects huge swaths of population in the Western United States is in much much larger public health burden.

And next I wanna share with you some results where we looked at different types of smoke waves looking at intensity and also timing.

So let’s just look at the left-hand side. So this is again, the percent increase of respiratory hospitalizations in this case, looking at smoke wave intensity.

And what you find here is that with as you move to the right-hand side of that left panel, the effect estimates go up.

What this means is is that when smoke waves are more intense, the risk goes up and you see a very clear trend.

And that makes a lot of sense.

On the right-hand side,
I'm looking at the days within the smoke wave. Again, this is really kind of analogous to a heat wave. So the first and second day is not where we see the largest health impact. It was really on a week, but really the third to seventh day of the week. And then the effect went down later. So there's really some interesting things that we need to start thinking about for when in a smoke wave to the highest health impacts for respiratory causes occur. You can imagine this would be really critically important if you were trying to do some type of public health intervention. Now, let's take these estimates of wildfire smoke and start thinking about them in the context of climate change. And here again, I wanna give you another little peek behind the curtain. So we generated this map at the County level showing changes in different smoke with characteristics under climate change. This is what I call a middle of the road climate change policy. So it's not everybody goes crazy lowering greenhouse gas emissions.
and it’s not everybody goes crazy raising greenhouse gas emissions. It’s a middle of the road scenario. And we’re looking at the change in the number of smoke waves from 2046–2051 representing the future. And this is really only for the fire season, to 2004 to 2009 representing the current day. And everything I’m showing you today is using state-of-the-art models. There’s no reduced four models here. And what I want to just know before he went to the details of this map is that we generated an online version of this map, where you can click on your County or County of interests and look at different features. Look at the demographics of that County, look at the anticipated future demographics of the County, look at different features of a smoke wave and so on. And we spend a lot of time developing this map. And then we just hired a Yale undergraduate who did it in like a weekend, super quick. And then I asked him, can I hire you to do some more work? And he was like, no, I’m going to work at Google. So we lost our great map builder.
But I think that my point I’m trying to make here is that this type of interactive map or some way are really helping get the results to a digestible usable format for decision makers in the general public is really critically important. And in some cases, it’s very difficult. And in some cases there might be some easier solutions than we had thought of. Like in my case, hiring a undergrad computer genius to do it so that we didn’t do it. So we have this map and we’re looking at the difference in the number of smoke waves. And in green that shows that those counties will have fewer smoke waves in the future than they do now. And then going up to red where they have many, many more smoke waves. And we’re gonna look at some other maps as well. And I want you to look at whatever section is of interest to you, but perhaps draw your attention to Northern California. So we see there that there’s really either goes down for the number of smoke waves or perhaps it goes up a little bit.
We don’t have a whole lot in Northern California. I’m just using this as an example. In Northern California where we go to this really high level, maybe those smoke waves last longer. So this is looking at the difference in the length of smoke ways where the previous one looked at the number of smoke waves. And here we see a different picture where we see again in Northern California, the smoke waves are not lasting as long. They’re gonna be shorter, but for many parts of the Western United States, in Colorado, Washington, Montana, Idaho and central California, the smoke waves are anticipated to last longer. And then finally looking at the intensity. So this is how much pollution is being generated by all these wildfires. And here, if we’d been looking at Northern California, we see that there really is a dramatic increase with Northern California having much more pollution from wildfires than they did previously. So another reason I wanted to show these maps is to show that these different characteristics of smoke waves that you use
in environmental health research more broadly can really dictate what the impression is to policymakers. And again, the false impression could happen innocently or it can happen on purpose but you could imagine someone looking at this map and just saying, smoke waves are gonna last a shorter period of time in Northern California. So perhaps doesn’t look like a big problem but really things are much more complex. And overall, our results found that under climate change we anticipate the wildfires to occur more often, we anticipate them to last longer and we anticipate them to burn hotter. I wanna raise the issue of environmental justice which I’m using in the framework that environmental justice is the concept and the reality that certain subpopulations suffer a disproportionate public health burden from environmental conditions. And I wanna talk about this in the context of wildfires under a changing climate. And again, Loretta Mickley was our wildcard modeler. And then the other photo is Lucio Woo who’s a former master student.
She’s graduated master’s student from the Yale School of the Environment. And this was part of her master’s research project. She did an amazing job. And so Lucio was interested in estimating what wildfire smoke looked like in Alaska. And so just to show you what that looked like, there’s a map showing that we see an increase in smoke from PM 2.5 from wildfires by the 2050s compared to the present day. But we also see a very distinct geographical pattern where some parts of Alaska see a very small increase and some parts see a larger increase. Well, Lucio was also interested in thinking about which populations we’re going to experience this increase. And she presented her work at a conference and meeting that involved many native American tribes in Alaska. And they gave her guidance on how to define the native American tribes for her research. So we followed their guidance, their self definitions. Of how they wanted this work done. And one of the things that Lucio notice is that the Alaskan Athabaskan tribe was really concentrated in certain parts of Alaska.
And you see there that six to 13%. And here what we’re plotting here are different native American tribes. Each tribe is a different color showing you the change or the smoke PM 2.5 exposure going from May to September, and is a function of where the tribes are located and where we anticipate wildfire smoke. You can see that this one tribe is really suffering a disproportionate burden of this anticipated increase in wildfire smoke under a changing climate. So large areas of Alaska would be anticipated to experience a double or tripling of monthly smoke exposure. So this is air pollution from wildfires by the 2050s, but there are very strong implications for indigenous people where these effects will not be experienced uniformly even across indigenous people in Alaska. All right, next I wanna share with you some ongoing and planned research with you some ongoing and planned research that we have for the future related to wildfires and human health and climate change. And I put this figure here just ’cause I think it’s neat. So anyone guess where my project is gonna be? You all know it’s Australia (chuckles).
So let me just start with these two projects that we have one ongoing and one’s about to get started.

So on the left, there’s a project led by Yuming Guo. His photo is the far left of that photo right at the bottom, his photo is kind of in the middle.

And Yuming is leading a project with many researchers around the world, including me and many, many others, but we’re looking at wildfires and air pollution in relation to a variety of human health end points.

So some of the advantages of this project is we’re really trying to go global and look at wildfires in different parts of the world.

And then the second project which is planned and we hope to start out into this summer is looking at bushfires which is the Australian term for wildfires, and air pollution and risk of birth outcomes in Australia.

And then I’ve listed the names there of the different collaborators, including Josh Warren who’s a biostatistician here at Yale, and then several collaborators from Australia from multiple three different universities in Australia.
And Yuming is in the middle there because he’s in both projects.

And so for this project, as you all know, Australia experienced devastating wildfires in recent years.

And for this project, what we’re really interested in looking at is how mothers exposure to air pollution from wildfires during pregnancy impacts risks of adverse birth outcomes, looking at things like low birth weight, preterm birth and a variety of other adverse birth outcomes. And we will be able in this project, we plan to also look at differences for the indigenous population as compared to the general population overall, and also to look at differences by socioeconomic position and other types of factors that could be effect modifiers and mean that some subpopulations might respond differently.

So I wanna highlight here again, the earlier work I showed from Alaska with Lucio Woo was looking at environmental justice with relation to exposure. In this work, we’re also looking at environmental justice in relation to response to a given health outcome. So they’re really multiple pathways.
617 00:26:34.240 --> 00:26:35.760 through which some populations could have
618 00:26:35.760 --> 00:26:37.263 a disproportionate burden.
619 00:26:38.970 --> 00:26:40.750 Given the sponsor of the seminar,
620 00:26:40.750 --> 00:26:43.890 I wanna talk a little bit more about some
621 00:26:43.890 --> 00:26:46.050 our ongoing work looking at air pollution
622 00:26:46.050 --> 00:26:47.400 health and climate change.
623 00:26:47.400 --> 00:26:49.240 This work is not wildfire specific
624 00:26:49.240 --> 00:26:53.070 although, we may look at wildfires in here as well
625 00:26:53.070 --> 00:26:54.310 but this is work that was funded
626 00:26:54.310 --> 00:26:56.940 by the Welcome Trust Institute that has Yuq-
627 00:26:56.940 --> 00:26:58.870 jang Zang
628 00:26:58.870 --> 00:27:01.030 and Northeastern University.
629 00:27:01.030 --> 00:27:03.730 And then you’ll see our collaborators
630 00:27:03.730 --> 00:27:06.280 from multiple universities in Brazil as well.
631 00:27:06.280 --> 00:27:09.270 San Paulo and Rio de Janeiro.
632 00:27:09.270 --> 00:27:11.730 And these slides are kind of wordy so I apol-
634 00:27:14.500 --> 00:27:15.740 But I’m gonna walk through our ongoing work
635 00:27:15.740 --> 00:27:18.227 and our plans for that.
636 00:27:18.227 --> 00:27:20.680 So we’re gonna use state of the science air
637 00:27:20.680 --> 00:27:22.390 quality and climate change modeling to look at what
638 00:27:22.390 --> 00:27:24.200 different types of air pollutants might look
639 00:27:24.200 --> 00:27:26.310 like in the future for these cities.
640 00:27:26.310 --> 00:27:29.520 And for those of you who work with air quality
641 00:27:29.520 --> 00:27:30.853 modeling,
642 00:27:30.853 --> 00:27:32.290 what that means is we start
off with a coarser spatial resolution and then use the results from that modeling brand as the inputs and boundary conditions of a smaller domain and so on. And this is a technique that’s been used for a very long time to get higher spatial resolution of estimates. We couldn’t computationally run the high spatial resolution for the whole country of Brazil, for example. So just to summarize, we really wanna understand air pollution and weather today and in the future. Whether the levels of air pollution and weather throughout these cities today will have very high spatial resolved estimates beyond what we could get from monitors. And we’ll also know what they’re anticipated to look like in the future for air pollution or climate. Next, we wanna link those exposures to human health. And we’re looking at mortality. Brazil as many of know is suffered greatly under the pandemic, and so we have had some struggles getting the health data from the government. This is not a criticism of them because they’re busy. So the public health departments in Brazil
are very busy dealing with more pressing issues.

So that has slowed us down,

but we still are getting mortality data

for one of our two cities

and we’ll hopefully get the other city soon.

So we really wanna look at how mortality changes

from air pollution, heat waves, and also single days

of heat and cold under the current climate,

and then we’ll estimate what

those concentration response functions

or exposure response functions might imply under

future conditions where we’ve estimated those exposure.

So we’re linking air pollution or weather and health today,

and then we’re using this estimates

to look at this in the future.

Just another point I wanna make

is I’m kind of peppering this talk with some

of my thoughts on climate change research in general.

I believe that it is critically important

to understand these systems in the present day,

before we start estimating what they look

like in the future.

So for example, I would like to know how people respond

to heat waves in the present day,
wants to respond to heat waves in the future. This is not a universally shared position amongst all climate change researchers, climate change and health researchers. And then there’s two more tasks of this work I wanna share with you that are really exciting. One is looking at sector specific simulations. So by this, I just mean that we’re gonna be able to distinguish between the air pollution coming from traffic, the air pollution coming from industry, the air pollution coming from other sources. And so we’ll be able to discuss and evaluate which types of sources of air pollution are more or less harmful. So here just to summarize what sources are most harmful.

And this relates to the comment I made earlier about wildfire particles could potentially be more or less harmful than other types of particles given the different source and the different chemical structure.

And then finally, we wanna look at co-benefits. So we’re gonna analyze what would be some potential greenhouse gas emission policies that could take place today, and what would be their impact on not greenhouse gas emissions but on air quality in the short-term.
So if we had something that, for example, change transportation patterns or increased public transportation that might be a policy for greenhouse gas emissions but it would also likely lower particulate matter.

Ozone, carbon monoxide and other pollutants in the near term, unlike the one to 10 year timeframe.

So this term is really most accurately called co-impacts but it’s commonly called co-benefits because they tend to be positive benefits.

And so we really wanna estimate what are the short-term improvements in air quality from climate change.

So next, I’ve allowed a lot of time for questions. I hope many of you are coming up with some questions or comments, but I just wanna give a few more just concluding thoughts.

I just have a few more slides.

So these are just some summary of the points that I tried to make today.

That they’re multiple complex pathways through which climate change and wildfires interact.

There’s changes in the type of fuel, so that’s what the wildfire modelers call trees is fuel.

So there’s changes in the type of fuel that could happen.
due to climate precipitation, as well as our anthropogenic management of forest, there's changes in the overall warming, there's changes in drought. It's really quite complex. And so we really take these estimates of wildfires in the future as kind of an overall estimate. We wouldn't look at like, what we think is gonna happen on July 5th, 2051 or something like that. The state of the science models from Loretta Mickley and others show that wildfires are increasing in frequency, duration, and intensity. You'll notice, I didn’t say is anticipated to increase. So that was done deliberately. So it was believed that the wildfires are already increasing in frequency, we’re having more wildfires, they’re overall lasting longer and they’re overall burning hotter. I wanna re-emphasize the point that exposure patterns due to where people live and where these smokes with fire takes place, the some populations are particularly vulnerable. Populations can also be vulnerable in other ways.

One is one group might have a higher health response
to exposure from smoke than others. Another is people might have different capacity to mitigate or adapt to these conditions like who can afford to move, who can afford filtration systems and so on. So there’s really a lot of complex interesting aspects of vulnerability for wildfire smoke. And even though, as I showed in that review article, there are uncertainties and a lot of research to be done, like looking at birth outcomes and so on, there is overwhelming evidence that wildfire smoke does have a substantial public health burden. And as we anticipate wildfires and wildfire smoke to be higher in the future, we anticipate that burden to go even higher. And we still have some remaining questions. Some of the remaining questions are by no means all of them, but some of them are looking at other health outcomes. Most of the work to date has been done for mortality or hospital admissions, but you can imagine there many other health outcomes as well, looking at vulnerabilities, which populations are most vulnerable from a variety of pathways such as ability to adapt,
There's a lot of work to be done on links to chemical composition; the particles from wildfires will have different chemical structures than particles from other sources, as different sources have different chemical structures and many more. And then I wanna re-highlight this point of co-impacts, which is commonly called co-benefits with climate change policy. So air quality policies are typically designed to protect human health in the short term. And then we have climate change policies that are designed to lower greenhouse gas emissions, but really many of the pathways through which these different policies take place can be similar. As I mentioned one earlier like changes to public transportation, changes to vehicle miles per gallon, lots of things like that. So many of the policies to improve air quality would actually lower greenhouse gas emissions, and many policies to avoid or mitigate climate change
would actually improve air quality in the short term. So I believe firmly that both air quality policies and climate change policies typically, have both short-term health consequences and long-term health consequences. This has been known for a very long time but still to this day, they tend to be studied separately and even bigger, they tend to be analyzed in policy domains separately. Not always, there’s a growing trend to look at this but overall, these policies tend to be looked at separately. And the point I’m trying to make here is that if we’re looking at climate change policies and we wanna think about, for example the cost benefits of a given climate change policy, if we are missing the links to improve air quality in the short term and those health benefits, then we do not have an accurate estimate of the implications of that policy and are not making an informed decision. This links back to my earlier slide about studies looking at the economic impacts of wildfires if we’re not incorporating the public health burden from wildfires,
then we’re grossly underestimating that as well and perhaps not making the most effective decisions.

There’s some references.

So if you asked me for a copy of the slides, I’ll be glad to share them with you and you can see some of our references.

And then finally, I wanna thank the people who really do the work which are my team, and you see many of them there.

And so thank all of you and I look forward to your questions and comments.

This is a wonderful presentation and I’m sure the audience all enjoyed like I did.

And I’m sure there will be a lot of questions.

But just a reminder everyone, if you have questions, please type it in the chat box.

We have roughly 20 minutes for the Q and A section.

But before that, I will start with some questions that we have already collected from the students actually.

So one of the question is kind of related to Michelle you mentioned that we should really try to understand better our present day before we try to protect the future.

So one of the questions from students
they notice that a lot of mechanisms are behind the climate change and wildfire. So how can we consider these unknown conditions or mechanisms when people want to do the future projection of wildfires? So how to consider this type of uncertainty? Yeah, so this is something.

There's some aspects of the wildfire modeling that we know work really well, and there other aspects that don't work as well, the same thing for estimating PM 2.5 more generally. So we can get pretty good estimates of PM 2.5 total mass, but we don't do as well and we try to look at the different chemical components. So there's really a lot of work looking at validating the models.
and seeing where it does well and where it doesn’t do well.

And where does well and doesn’t do well could be in a literal where,

like it may do well in some topographies than others,

it may do well under some conditions than others.

And really my understanding from working with the wildfire modelers is that we really wanna think of these as kind of large-scale estimates.

So one of the things that we’re looking at for the project we hope to get started that we’ll be looking at wildfires in Australia, it does improve the underlying emissions inventory.

So Loretta and her team have gone through the different pathways and trying to identify which ones are contributing the most to our uncertainty,

and which ones are perhaps not perfectly captured by the model, but still maybe not making this big an impact on our estimates.

And they have found that the underlying emissions of wildfires, this incorporates things like the fuel, the type of fuel by which I mean trees and vegetation, that that’s really critical.

So one of the main contributions that we’re gonna make,
and I really should say that Loretta and her team are gonna make to Australia is to improve those underline emissions inventories.
And then we will be making those publicly available for other people as well.
I just wanna highlight that some people have asked for a copy of my slides and I put my email in the chat.
So if you’re interested in a copy of the slides, I’d be glad to send them to you please just shoot me an email, thanks.
Thank you Michelle.
I think your talk illustrated the complexity of this multidisciplinary work.
So another question from the students they’re more interested in how the local communities can do about it in the short term kind of mitigation’s way.
So can you share some of your suggestions the local community when they’re facing the danger from climate change health can they do about it?
Yeah, I wanna share a slide actually.
Can you see my slide, did it work?
Yeah, okay.
So this is a figure that I just didn’t include.
an individual level protective measures from our review article. And here you can see we've kind of started at the top with most effective which is to eliminate the exposure. And so this is all based on the individual. This is not based on a like a federal policy. There's many other things they could do as well. So the first one, the biggest impact is to relocate, right? That could be permanent or temporary, but like to temporary relocate when there's wildfires. You cannot get away from this with filters. Filtering industry doesn't like me to say that, but it's true. And then what we call administrative controls. So I'm gonna take a little bit of water. This vaccine is no joke. But yay science, I'm happy for it. So the third level down to shown in the kind of page is administrative controls. So that's things like staying indoors, avoiding heavy activity outside and so on, and then personal protective equipment like wearing a face mask and so on.
And so you can see if we were to unpack this a little bit further, some of these activities are easier than others like wearing a face mask, it’s not that hard. Some of them are harder than others, like to literally leave your home. Some of them may be more feasible for some people than others, like the financial cost of relocating, financial cost of filters. And some of them have other implications like social and cultural implications. Like, what does it mean if children can’t play outside for months? So all of these things are really, I don’t wanna say bandaid solutions, but none of them are fully satisfactory. But there are a variety of things that we’ve come up with to kind of highlight some things that an individual can do. But really what we’d love to do for exposure is everyone who works environment exposure knows is to stop the exposure itself from happening, rather than trying to address the public health on the backend. There’s a question from the audience from Glenn Homan, are children more vulnerable to the effects of wildfires. So that’s a really great question.
And so I’m gonna couch it in two parts. So the first answer is we really don’t know because there hasn’t been as much research. The second part of my question is I would suspect yes. So children tend to be more vulnerable than healthy adults to air pollution in general. And there’s a variety of reasons. Their systems are still under development. They breathe in more air per body weight than do adults and they historically spend more time outside. Although that’s actually changed in the last few generations but historically they spend more time outside. So there’s a variety of reasons why children are more susceptible to air pollution. They’re larger than are like other healthy adults. Now, much older populations are also susceptible as well. And so while we don’t have the evidence the strong evidence for this for wildfire smoke, I think it’s certainly very plausible and I would argue likely. that some of those same mechanisms would take place for children in wildfire smoke as well. But this is certainly an area where we need some more studies to really pinpoint it.

<Thanks, Michelle.>
So I know we talk a lot about short-term effects here. And the students are also wondering like what can the policymakers do to better report or even do research on the long-term health consequences of the wildfire exposure? Yeah, so I didn’t mean to talk over you.

No, no, no, the student’s question is just.

Yes, so there’s a lot there. And in the review article, we categorized the health impacts of long-term exposure to wildfires as being more uncertain. So again, I’m gonna kind of answer this in a few different parts. Much more is known about short-term effects.

Again, it seems very plausible that both will play a role. Because they do for particles more broadly, right?

Short-term exposure and so by this I mean my exposure today.
and over the past few days, maybe to a week, maybe in that timeframe matters for my human health. But my exposure over the past several years matters. And actually my exposure in neutral matters, like everything matters. We don’t know as much about that for wildfires. Some reasons why it’s important to study and difficult to study is that the concentration levels for wildfire smoke are very different from other pollutants. As I mentioned, it’s like nothing, nothing crazy high, nothing, nothing. So what does it mean if you’re getting those stressors or those crazy high? If you’re getting it several times a year or every year, year after year, as opposed to just the impact from getting it once. And that’s very different from kind of like my exposure to traffic particles, which is just going up and down, changes day to day of the week and so on but really is not having these strong events. So it’s really these kinds of like huge stressors that come and go away and come and go away.
So to understand that we need things like knowing where people have been for several years.

We need really good estimates of wildfire exposure over several years, and I predict that some of the future areas of research for this will deal with some of the things on that previous slide relating to the other good question about individual level protective measures.

This group of people had a pec major filtration systems and trying to stay inside, and these people were not able to. There’s a lot of things there that we really need to parse out to really try to get a handle of long-term exposure.

Thanks, Michelle, there are many other questions. Thanks, Michelle, there are many other questions.

From the students regarding especially on the review paper. But I also encourage the audience if you have questions to the whole talk, so please feel free to type in your questions. Or if you like, you can unmute yourself and ask the questions.

I would just ask them one more question from the students. Kind of related to the individual level what the local communities can do,
One of the ways is prescribed burning to mitigate the wildfires. So several students are kind of interesting, as a policymaker, how can you determine whether, just let it burn or do something additional about it. And students are wondering if there are any studies to look at this prescribed burning can we see does it cost effectively prevented the wildfires? Yeah, so the prescribed burning question is very interesting. There have not been as much study on the health impacts of prescribed burn, but air pollution is air pollution. So prescribed burn which is being done is a forest management strategy is also producing air pollution. And so it’s very interesting talking to communities and decision-makers on their different, enforced managers on their different perspectives and the different angles at which they’re coming at this issue. So for many people in the community like all fires are bad in their perception, whether it be prescribed burn to stop a larger fire leader or whether it be a wildfire.
because they’re getting the smoke of it regardless.

And from a forest management perspective, you often will have prescribed burns deliberately to try to avoid that things later on.

And I’m not a forest manager, but like these are done based on scientific research that we need to do this to control our forest.

And then from a climate change perspective, we have to think about what does this mean for prescribed burns and the changing in vegetation patterns.

Are we gonna have more prescribed burns? Are we gonna have fewer prescribed burns, but like what should we do for prescribed burns is very delicate, especially in terms of the research for air pollution.

And I think that’s part of why most of the research has really focused on wildfires.

I think Rob may have been trying to chime in

Rob, were you trying to chime in?

Yeah, the first great, great talk, Michelle.

Yeah, I know your research focuses on the wildfire smoke and air pollution, but there’s another element that I wonder if it’s something that you’ve considered
which is the help that when there are wild-
fires,
people are displaced sometimes short term, 
sometimes longer term, you know people lose 
their homes 
and their lives are disrupted 
there are potential health effects of that 
that could be disruption in medical care. 
And from what I’ve gathered, those longer 
term effects, 
those types of effects have really been under-
studied. 
And I’m just wondering 
if you have any thoughts about that aspect. 
Yeah, this is a really great ques-
tion</v>
and I wanna kind of unpack several things. 
So there’s a lot to learn about 
our response to environmental disasters. 
And what does that mean in respect to hu-
man health?
And what does that mean for respect to 
physical health?
What does that mean with respect to mental 
health?
What does it mean in respect to disruption 
of healthcare?
There’s some really great work that was done 
by a former master student, Leo Goldsmith 
who looked at a variety of ways 
in which the LGBTQ community has dispro-
portionate impacts 
from environmental hazards.
But one of them is disaster response
where LGBTQ+ individuals are turned away at shelters,

don’t have access to their medication and so on.

And then there’s the also the issue of who can afford to move.

There’s also some great work being done by my PhD student Kate Burroughs, looking at displacement.

And I think it’s something that probably needs to be looked at and I’m expanding it out to disasters more broadly.

So like hurricanes, wildfires just the environmental disasters that we anticipate to be growing under climate change to happen more often to happen in a more intense way,

what does this mean for the economic and health costs of relocation?

What does it mean for the economic disruption of that community if people have to get up and leave?

I mean there’s all sorts of things that communities have talked about with me and wildfires in terms of things like my housing price.
And there's designs of homes where you can try to make sure you don't have brush near the house so that if it's a wildfire it doesn’t zoom up on your house and so on, and these things, it was very clear to me that these things are taking a mental toll as well. So I think this is a very understudied issue and I think there are multiple facets to it where different populations are affected differently. And this is something we really should be looking into.

Can I answer the question in the chat next? Kai, is that okay?

Yeah, please go on. Okay, great.

And this is from Evan Brockman. We are discussing what to add to our EHR as clinicians what changes would you like to see in data collection in regards to air quality? We are discussing what to add to our EHR as clinicians who directly see patients who suffer after exposure, thank you. So with respect to data, I’m not sure if the person that’s in the question is thinking of health data.
or air pollution data. It kind of seems that maybe health data
but I'm gonna answer all those questions (laughing).
So with respect to air quality, we really need more monitors in rural areas,
not just to try to study those populations 'cause they're different but also the air pol-

could be different as well. We are really hindered.
This is worldwide by having our monitors being predominantly located in urban areas.
With respect to human health, I think that there's some types of data sources
for human health that we can get a pretty good handle on,
like hospital emissions, mortality and other things that it's much harder to get a handle on.
And just to get back to Professor Dubrow's point,
like mental health and wellbeing.
And so I think that some of those perhaps under the surface types of health outcomes
that could have an enormous public health burden
are ones that we really probably should start looking at
more in relation to air pollution.
I hope I've answered your question. I'm not sure if I misunderstood it, thank you.
Michelle, I think there’s another, yeah.

Okay, I’m gonna ask this, is the dense network of low cost air quality sensors good enough to serve as input to your models.

Well, it depends on the model and on the monitor. So we’re often modeling at a nation level. So we would need like a huge network. And the low cost air quality centers, so cost and quality are associated in air quality monitors. So a low cost monitor can measure very, very well depending on what it’s measuring or it might not, that’s not a negative comment on those monitors. Sometimes that’s perfectly good for your purposes. So I guess my short answer would be, it really kind of depends.

Michelle, I have a question, all right?

You mentioned that I think why you initiated this study to look at the wildfires because when you look at previous reports on almost no damage was taking into account with the health burden, I think it speaks true for all the other extreme weather and climate change.
So would you like to share more source more broadly
the economy burden on climate change
and how as a researcher, what we should do about it?
Yeah, so I think that is, I alluded to
I think that human health is missing
from part of the climate change discussion.
And by the discussion I mean, in political decisions
in the general press and the mass media
and in community discussions.
And so there’s a very different response to learning
that sea level rise might impact a country halfway
around the world, as opposed to learning that asthma rates
in your community are likely to go up.
We can discuss the ethics of that, but that’s a reality.
And I showed that slide at the beginning
of the climate change human health articles
have really been skyrocketing, but I personally believe
it hasn’t really caught up
with the kind of the general discussion.
So still when people talk about climate change
they’re often not talking about human health
or not as much.
And if you look at the predominant reasons
that people have moved on environmental issues,
the number one reason people care about the environment is human health, although other things matter. So I think that’s why Yale center and other work on the human health impacts of climate are really important for people to really understand the full magnitude of what climate change means. We’re not just talking about loss of species, we’re not just talking about loss of land, we’re not just talking about ecosystem changes but we’re talking about actual changes in human health, which will be a huge driver for many people. Thanks Michelle, for the very insightful comments. And I think we do have the last comment from a Pin Wom, thanks for the informative talk. How was the threshold for smoke we’ve determined. As you mentioned the smoke pollution is like non-crazy high num pattern. How important was the definition of threshold in this study? Yeah, similar to how you might do with heat waves. We used a variety of thresholds, so we varied it. And we saw results that you would anticipate.
So as we made the requirement more stringent,
meaning we’re forcing those smoke waves to be more extreme.
We saw higher health impacts.
And then if we lax the response
and allow the smaller smoke waves
like you still have walked our air pollution,
but it’s not as high,
we still saw an effect and it was lower.
So I guess the short answer is it matters in terms
of your specific numerical health effect estimate.
But it didn’t matter in the sense
that we found effects at different types of definitions.
And this makes sense too
because there’s nothing like magical,
like two days matters, but three days doesn’t,
two and a half to, you know what I mean?
So these are all like approximations.
They’re just trying to capture the smoke wave period.
Wonderful, thank you Michelle.
I think I can speak
for the whole center and all the audience.
Thank you for giving us a wonderful and informative talk.
And thank you all the audiences attending today.
I think at a peak, we have almost 90 audiences.
Oh great, thank you so much!
for the invitation to share my work.