Okay, let’s get started. Can you hear me okay at the back? Yeah, okay, great. So I’m Robert (mumbles) I’m a professor of epidemiology in our Department of Environmental Health Sciences. And I’m also the Faculty Director of the Yellow Climate Change and Health Initiative. And we’re very pleased today as our first speaker of this academic year to have Jason West, who’s from the Department of Environmental Sciences and Engineering at the University of North Carolina School of Public Health. And we were just talking about how few public health departments have engineering in the name and how actually valuable it is to have engineers within schools of public health, as hopefully, I think you’ll see when you see the work that Jason does. So Jason, has a great publication record he’s published in the high impact journals like and has a the National Science Foundation, including the EPA has a the National Institute of Environmental Health Sciences. And so he’s got, as you know, he’s gonna talk.
0:03:21.98 –> 0:03:24.67 to you today about connecting climate change,
0:03:24.67 –> 0:03:27.063 air pollution, energy and human health.
0:03:29.896 –> 0:03:33.063 (students applauding)
0:03:34.17 –> 0:03:35.6 - So I’m really happy to be here today.
0:03:35.6 –> 0:03:37.67 Thanks for the invitation.
0:03:37.67 –> 0:03:41.33 I spent yesterday, an exciting day for me in New York City
0:03:41.33 –> 0:03:43.84 for the climate week, and–
0:03:43.84 –> 0:03:46.697 - Sorry, (mumbles) to just the lights a little bit.
0:03:46.697 –> 0:03:48.28 - All right, yeah.
0:03:48.28 –> 0:03:52.83 I was just gonna say, I was having a hard time in my mind,
0:03:52.83 –> 0:03:55.4 justifying flying up here just to attend
0:03:55.4 –> 0:03:58.35 a climate change event in New York.
0:03:58.35 –> 0:04:01.11 I had thought instead of about maybe taking a sale
0:04:02.097 –> 0:04:02.93 (students laughing)
0:04:02.93 –> 0:04:06.22 but then I contacted Rob who had already invited me
0:04:06.22 –> 0:04:09.53 and asked him if we could combine my trips.
0:04:09.53 –> 0:04:11.11 And that worked out really nicely.
0:04:11.11 –> 0:04:13.47 So Rob, if nothing else, I should thank you
0:04:13.47 –> 0:04:17.47 for making me feel less guilty about flying.
0:04:17.47 –> 0:04:21.48 Okay, so I’m gonna talk to you today really,
0:04:21.48 –> 0:04:23.96 this is a talk not on one theme,
0:04:23.96 –> 0:04:25.81 but I’ll be talking about a lot of the work
0:04:25.81 –> 0:04:29.64 that I in my lab is done over the past decade or so.
0:04:29.64 –> 0:04:32.48 I’ll motivate that in a minute by talking about
0:04:33.68 –> 0:04:36.06 especially the human health angle,
0:04:36.06 –> 0:04:39.19 that the work we do is really pretty interdisciplinary.
0:04:39.19 –> 0:04:40.26 And I think you’ll see that
0:04:40.26 –> 0:04:43.69 so I work on climate change in air pollution.
0:04:43.69 –> 0:04:46 My main entry point to climate change is
0:04:46 –> 0:04:48.9 through atmospheric science, which is kinda my back- 
ground.

0:04:49.74 –> 0:04:53.64 But in particular, this interest in climate change

0:04:53.64 –> 0:04:56.74 has kinda taken off in connecting climate change

0:04:56.74 –> 0:04:57.573 with air pollution.

0:04:57.573 –> 0:04:58.75 So as climate changes,

0:04:58.75 –> 0:05:00.88 what will that mean for air pollution?

0:05:00.88 –> 0:05:04.41 Or as we take the necessary steps to address climate 
change,

0:05:04.41 –> 0:05:06.91 what would that mean for pollution and for health?

0:05:06.91 –> 0:05:10.39 So those are a couple of the themes that are explored 
here.

0:05:10.39 –> 0:05:12.14 I thought I’d start with this paper,

0:05:12.14 –> 0:05:15.513 which Michelle (mumbles) here also contributed to.

0:05:16.37 –> 0:05:18.173 That appeared a few years ago.

0:05:19.07 –> 0:05:21.69 I and colleagues this, if you look at the list

0:05:21.69 –> 0:05:26.15 of authors here, this is a purposeful combination of

0:05:26.15 –> 0:05:27.51 air pollution scientists

0:05:27.51 –> 0:05:29.42 and air pollution health effects scientists,

0:05:29.42 –> 0:05:32.09 we all got together in a room and talked about

0:05:32.09 –> 0:05:34.93 what were some of the big issues of our day

0:05:34.93 –> 0:05:37.237 trying to take stock of what’s known about air pollu-
tion

0:05:37.237 –> 0:05:39.88 and health, and what are the big opportunities

0:05:39.88 –> 0:05:41.47 for the future.

0:05:41.47 –> 0:05:45.52 Some of our main conclusions I’ve pointed out here,

0:05:45.52 –> 0:05:47.61 one is how important air pollution is

0:05:47.61 –> 0:05:50.04 for global public health.

0:05:50.04 –> 0:05:52.63 And what’s been really instrumental in coming

0:05:52.63 –> 0:05:54.05 to this understanding has been

0:05:54.05 –> 0:05:55.92 the Global Burden of Disease Assessment.

0:05:55.92 –> 0:05:58.61 So as I go along, through this presentation,
I'll show you some results from the Global Burden of Disease Assessment and show you how my lab is doing some work to contribute by mapping global surface ozone concentrations. Air pollution, its health impacts our changing globally and will change in ways interrelated with climate change. We looked also at air pollution science, which is making new possibilities through new ways of measuring air pollutants, measuring new chemical constituents that may be then we could put in epidemiological models to find out what component of air pollution is most important for health. We also have cheap sensors that can be widely deployed and are being widely deployed, providing a lot more information, even if the quality of those measurements is poor. We have satellites looking down at the world now giving us information every day about air pollution that's potentially useful for us. And computer models and that's what I do are becoming better for this kind of application too. One of the reasons why I wanted to start off with this, was we took some time in this article to talk about the need for the air pollution science community to work better and closer together with people that work in air pollution, health effects science.
So when I think back to when I was a graduate student, I was firmly in the air pollution science world. I was not exposed at all really to help. And as I look out at even our air pollution science meetings, those are changing that I now see more presentations from health effects scientists or people that are making this bridge between air pollution science and health effects science. So that’s a healthy change, but I think we have a long way to go still.

Okay, in that regard, and maybe some of you will be interested to, in your career fill that void. Okay, my plan for today is to it’s sort of the buckshot approach (mumbles) I’ll talk about a lot of different themes, and we’ll see if any of them stick with you.

But first, I was gonna talk about global ozone and what drives global ozone changes? This is more atmospheric science. But the rest of the talk will be about, about air pollution and climate and health. So how many people die each year due to exposure to ambient air pollution? How can we best model global surfaces on distributions that’s for the Global Burden of Disease? And I’ll show you those results.

How will climate change affect global air pollution and air pollution related deaths? So now turning our attention to climate a little bit. What are the trends in air pollution related deaths focusing on the United States?
And the last question, if we slow down climate change, what are the benefits that we would see for air pollution and health, okay?

Good.

I’ll talk a little bit about ozone.

So I’m guessing many of the students in here (mumbles) from a public health are studying public health and maybe don’t know a lot about ozone. So let me talk about that.

So oozones forming the atmosphere by an interaction of non-methane volatile organic. So organics that come from motor vehicles and trees emit volatile organics, those drive this cycle of radicals.

The other important ingredient is nitrogen oxides, which comes from motor vehicles and power plants, in the presence of sunlight gives us ozone.

So the three important ingredients are in organic sunlight, and out of those chemical reactions, we get ozone.

And when we look at the global scale, these fast reacting organics that are important in a place like Los Angeles for producing ozone very fast because these react on the order of hours are not very important than these more long live compounds.
So carbon monoxide is really an important methane really important.
Okay, so methane is admitted in large quantities, but it reacts so slowly contributes very little to urban air pollution.
But on the global scale methane is one of the big drivers.
Okay, so and by the way, methane and ozone are both greenhouse gases.
So going back several years, I had a line of research looking at how emissions of these different precursors would affect both methane and ozone thinking about how do you control those, both from an air pollution point of view and from a climate point of view, okay.
So as you motivate the first study here.
We’re interested in here in how global emissions are changing.
This shows global emissions of nitrogen oxide one of those compounds that reacts to form ozone.
So by the time we got to 1980, you see the emissions are dominated by the U.S and Europe.
The spatial distribution, this is the latitude and they’ll distribution on the right here, that hasn’t really changed as emissions grew.
But after that period, then this is 1990, 2000, 2010, we see emissions going down here in the U.S and Europe as we’ve implemented air pollution controls.
And they’ve gone up pretty dramatically now in China and India. So the emission distribution is shifting southward. This is interesting, and perhaps troubling, because we understand from the point of view of atmospheric science, that a ton of emissions closer to the equator is expected to cause more ozone to be formed.

And so we’re asking the question here, basically, we'll focus on this period 1980 to 2010. So 1980 years before we had this change in the spatial distribution with emissions coming southward. We’re gonna separate out the importance of the magnitude of the emission change versus the spatial distribution. And the third ingredients here and the third factor that’s really important is the global methane change. And we’re gonna see how important each of those is for global troposphere ozone.

Where it’s increased the most is an indicator of where the biggest growth in emissions in the ozone has taken place, especially South and Southeast Asia. And then the contributions to this total.
So 28 Tera grams of ozone contributions from the change in spatial distribution, the magnitude change and the methane change, these two on the bottom, though they contributed to the total amount of ozone present, have very little ability to explain this pattern of the total lows on growth. But if we look at the spatial distribution change, we have reductions in ozone, reductions in emissions, I should say, from the U.S. and Europe, but pretty dramatic growth in South and Southeast Asia. And this gets us a lot further at explaining this total ozone growth. We were actually surprised by this that this is over half of the total, bigger than the effect of the magnitude and the effect of the methane change. This is another way of looking at this where this is the I should stay close to the mic, I’m told because we’re recording. This is the equator, the North Pole, the South Pole, and then looking through the depth of the atmosphere here. This is the total change, the spatial distribution change, the magnitude change, and the changing global methane. In all of these cases, I should say in these two on the bottom, again, you don’t explain the pattern that you see in the total ozone change. And this helps us to explain why this is so important. So as admissions have shifted, further southward, close to the equator now, those emissions are being lifted.
up by deep convection, we would say in a meteorological sense, reaching a higher level in the atmosphere than they do here. Once those emissions become part of the upper troposphere, they live longer, and they react to form ozone. That’s what’s driving this greater sensitivity of ozone to changes in our pollutant emissions near the equator. And you can see that really vividly here that these emissions that are from Southeast Asia in India are being distributed, lofted up very high, where they’re reacting to form a lot of ozone. So our concern then was that as we shift and continue to shift emissions toward the equator, that even if global emissions might decrease, if we’re if the spatial pattern is changing, we might continue to increase global ozone. This was the work of Yuqiang Zhang who is my PhD student and that postdoc, he’s continued to do bunch more simulations where he’s separating out then the influence of each world region change at the change from 1980 to 2010. Looking at the influence of each world region change on the total ozone change, here’s the methane change as well. So this is the total effect. And we see here that East Asia is important, that’s China. That’s not surprising, they led the world in...
manufacturing with huge emissions associated with it. What is surprising here, is right next to it is Southeast Asia as important for globalism. And if we look at the emissions, the emissions from Southeast Asia are much smaller than the emission growth that’s taken place over these three decades from East Asia. So we’re really highlighting here how important emissions are, that are near the equator, and in particular, from Southeast Asia, suggesting that there really are sort of emission hotspots where each ton of emissions has a much greater influence, on global air quality than emissions from further north, okay. So that’s your bit of atmospheric science today. I’ll turn our attention to health. And our first question will be, how many people die each year due to exposure to ambient air pollution? I’m gonna take a minute and get into that. So, Rob introduced me as an engineer and my background is engineering. I had no schooling and public health had no idea what public health was about, really until I did this study, I had been for a few years, I had a fellowship to work in UPA headquarters in DC. So there’s a fellowship program for PhD scientists to go into government offices.
And I thought at the time that I’d be leaving academics for good to pursue a career in policy. And I learned a lot about how people formulate policy questions in a place like DC. And that changed how I approached problems. So I became interested in health. Health is an interesting topic, but my main motivation actually was to think about it from a cost benefit of policy analysis point of view. The health was, to me the benefit of the cost benefit analysis. That’s why I wanted to study it. So my first study, there was I became aware as I just explained to you that methane affects the global background of ozone. We had been thinking about methane, obviously as a greenhouse gas. And there’s good reasons to reduce methane as a greenhouse gas. I thought I look at it in different contexts. And I asked the question, could we justify reducing methane emissions, because of it’s reductions in ozone, and the health benefits that would come about from that? So this was published in 2006. I called up Michelle Bell, who had the number one paper on ozone related deaths and I talked through with her. How do I use that information in
what I’ll call now a risk assessment?
So using epidemiological information to assess health.
So what I did here was I use my global atmospheric model,
put in a simulated a 20% reduction of global methane emissions,
overlaid that on the world’s population,
and found that the reduction who knows on that came about
from reducing methane avoided about 30,000 deaths in 2030.
When I put dollar sign associated with those deaths,
and compared it against the cost of reducing methane,
and I could look up from the climate literature,
the ways that we could think about reducing methane
and how much it costs, I found actually that the benefits
to health outweigh the cost.
So that was kind of cool.
And it’s suggested that we could be thinking about methane
controls from an air pollution management point of view,
as well as from climate change management point of view.
Okay, but one of the things that I was only vaguely aware
of at the time, this was actually the first time
or certainly one of the first times that anybody had used
global atmospheric model to drive a health impact assessment.
And what I wasn’t anticipating at the time was,
that would be that the major direction of my research
ever since that, okay.

So what I’ll talk to you through now

or some more applications,

where I’m using my global atmospheric model,

or using models that are used in the community

that I came from, and now using them

for Health Impact Assessments.

So the question that I asked just go back a couple slides

how many people died prematurely due to exposure

to outdoor air pollution every year?

If we look back several Global Burden of Disease Assessments

ago, the first answers to those questions only looked

at cities because it was in cities

that we had observations

we didn’t have observations elsewhere.

And so they were only estimating in the

Global Burden of Disease, the effect of air pollution

on health for the fraction of the world’s population

that lived in the city, ignoring everybody else,

but we know where pollution is going up in a lot of places,

even rural places.

So our first attempt at doing that was

that you use a computer model, the computer model

has an advantage because it’s got

complete quote global coverage.

It’s got disadvantages, of (mumbles) grid cells

don’t really tell you what people are breathing

in an urban setting.

And it’s got biases, okay.
But nonetheless, we used it and that gave us the first estimate of global air pollution related deaths as a global total. Here was the next study in that line. This is Raquel Silva, who is my PhD. I use a bunch of chemistry and climate models. These are simulations that were run for climate research, but they also output ground level concentrations of ozone, and PM2.5 and one of the neat things is they simulated today, which in this study was year 2000. And they also simulated the year 1850 as being before the Industrial Revolution. So we took the difference between air pollution in 1850 and 2000 and called that human caused air pollution. And then assess what that meant for global human health. So these are a bunch of different models that all ran the same experiment. This for ozone, you see, there’s a spread of different results, using the different models. When we looked at this, this is the average of those. But the error bars here reflect both the uncertainty and the concentration response function, the spread that we get from the different models. And it turns out that the uncertainty that comes from the spread of the different models, outweighs the uncertainty contributes more to this overall uncertainty, then does the uncertainty and the concentration response function. So that was kind of interesting as well.
But globally, half a million or so, deaths related to ozone, related to PM2.5, about 2 million deaths.

In a minute, I’ll put those numbers into more context for you, you know, how do we think about that and how do we compare what that number means? I’ll just finish talking about this study. This is the average of the many different models we use. This is for ozone, with most of the world’s deaths occurring in India and East Asia, obviously huge populations exposed to highly polluted air.

Here, we’ve looked at it deaths per million people in these different regions, it’s certainly higher there. But even North America stands out is pretty high as well there, even though air pollution is has gotten less severe through time, okay.

And in East Asia, I mean, (mumbles) PM2.5 half the global total is in East Asia or so, okay. So that’s an example of the type of work that we can do, addressing this question. Will come back to that question when we look at the Global Burden of Disease Assessment.

This was our contribution to the Global Burden of Disease Assessments, where my lab is now looking at the statistical methods for how we can best model global surface ozone concentration. So we wanna understand all around the world
what people are breathing at ground level.
The challenges that we’ve got a lot of measurements
de measurements of ozone air pollution in the United States and Europe and much less elsewhere.
And I’ll show you later we have huge voids where
of Africa for example, where there’s very few observations.
So going beyond where we started,
which was let’s just use a model to estimate what people are breathing.
Now we’re going to fuse together in a statistical way the global surface ozone concentrations,
I’m sorry, the global ozone observations and an ensemble of global models, okay.
So we have a big team working on this we’re working with Owen Cooper and Kai-Lan Chang.
Owen is the chair of what’s known as the tropospheric goes
They’ve compiled together, this is the biggest compilation of ozone related measurements
that it’s ever been put together from all around the world going back several decades, actually.
So that was a huge undertaking, including, you know,
calling up the government of Iran, and asking them that they would share their ozone data.
There’s a lot of work that went into that.
I’m using a bunch of models that come out of what’s known as the chemistry climate model initiative.
And then we have a big team of people in all especially mentioned, Marc Serre, who’s a space time statistician who works in my department, and will use his methods here.

I’ll explain that in a minute, okay.

So Kai-Lan led our first study which was published this year, where we’re combining, again, the observations and output for many models, and we’re using here this health related metric, we’re doing an average of several years.

And the health related metric was requested by the Global Burden of Disease Assessment, because this is how they’ll assess human health.

Okay, so the big the picture we take tour observations this is what those look like.

Again, a lot of observations in a few places, but other places very sparse observations.

We have the, this is the multi model average, the average of all the models that we’re using, you see that this is biased high, so we wanna correct that bias.

Then combine these together, I’ll talk about the steps that we go through to do this, to create this output map that was delivered for the Global Burden of Disease 2017 Assessment.

So I’ll go through the steps that Kai-Lan did in this study.

First, he did a spatial interpolation of all the measurements which is shown here.

He looked at all of the models, these are the models listed.
And he did a full evaluation of each model with respect to all of the observations. Here is really the key to what Kai-Lan did, he found in each region of the world, so for North America, Europe, East Asia, et cetera. The combination of models that best represents the measurements, the best reproduces the measurements. So he is like an optimization routine that he goes through to find the linear combination of models that best reproduces the measurements. And he’s correcting bias while he does that, that gives us this multimodal blend. And the last step is where we have observations, then we’re gonna correct within two degrees of those observations. The two degrees is fairly arbitrary, and I’ll talk about that choice next. But we correct for the observations within two degrees of the observation. And this is our final product. So in the U.S where we had a lot of observation stations, it’s going to because of this last step, basically be based mainly on the observations in a place like Africa where we have very few observations our output is going to be based mainly on the models. Okay, so that was our first attempt at it, which was produced for the Global Burden of Disease 2017.
And we just finished our work for the new forthcoming Global Burden of Disease 2019. Here we did quite a few steps to improve upon that. We’re now producing ozone maps for all years, from 1990 to 2017. Where you perform a new data fusion method that I’ll explain in a minute, which is Marc Serre’s method known as Bayesian Maximum Entropy. We add new observations from China and elsewhere. China really started measuring in 2015 or so. Now there’s hundreds of stations in China operating which were not up operating before. And when we do this, we have really the observations if there’s a lot of observations that can give us spatial information on a fine scale, such as around an urban area, but again, many places in the world have very few observations. So what we did is the last step was to use this NASA model that simulated the whole world at one eighth of a degree resolution. To add that find space or spatial structure output product is for the whole world, each year over this period, at .1 degree resolution. So we’ve delivered that to GVD, they’re gonna use that. I’ll explain the Bayesian Maximum Entropy method. So we use the output of the multi model blending that Kai-Lan Chang did. So we’re now doing that and each year,
that becomes in this framework, a global offset, which is shown in blue, the BME method would in suppose these are observations around it. So the BME method would exactly match an observation at the location of the observation and the influence of this observation. If you’re very far away from the observations, you’re gonna use the global offset which is this model output, so basing it on the models, and the influence of these observations falls off with distance from the observations. And that function by which it decreases with distance is a function of the spatial correlation of the observations themselves, okay. I’ll talk more about that in a minute. So, the features of the output is that we’re gonna match observations, where we have observations and far from the observations, we’re gonna tend toward what the models are telling us after we bias correct them. I should say, though, this shows it in space, but we also do this in time actually. So we use information in different years. It’s often the case that a monitoring station will come online in a particular year. We can use information from those monitoring values and use that to inform the years before that, okay, in a statistical sense, where again, the further we get away from it,
the influence of those observations falls off with distance or time. This is what those correlations look like. This is a covariance function with distance from the station. So spatially, it drops off quite a lot such that by the time we’re one degree away from an observation, we’ve lost a lot of useful information. But in time, it drops off actually very slowly. So, one, this is to say that one year’s observations is useful for informing the years around it, and we make use of that here, okay. So our final product, I’m just showing you results for a single year, but we’ve done this for all years over this period. We started with the observations. This is a multi model average which is bias high. If we go through this step of our first sort of methods of combining together the different models in an optimum sense, this is an correcting for bias. This is the result that we get. And then our final product, which doesn’t look all that different from that one. But if you look at details around in urban area, for example, especially where we have measurements now, this is doing a lot better at reproducing those measurements, okay. So the most recent global, we’ve delivered that to Global Burden of Disease.
that’s gonna come out in the forthcoming assessment, but these are the results that I’ll take a bit and talk about to put air pollution related deaths into perspective. This is from the 2017 assessment that was done. So, Ambient PM2.5 pollution, that’s 2.9 million deaths, Ambient noise, pollution, about half a million deaths. The third one here is household air pollution from solid fuels. That’s people burning coal, and straw and wood, within a home environment, often where there’s very poor ventilation. So this is not in the United States, but in the poorest regions of the world where people don’t have access to electricity and things like that. So that’s 1.6 or so million. If you were to add up PM2.5 and ozone, that’s one of every 19 deaths globally. And what the Global Burden of Disease Assessment does is they assessed a whole bunch of different risk factors such that you can compare them against one another and here’s Ambien PM2.5 pollution, coming in at number 10th in this list, if you only looked at death, it would be the number eighth most important risk factor but look at the things around it. So I think if you were to ask people, what’s most important for health first, you know, PM2.5 pollution
0:33:44.65 –> 0:33:47.2 is the number one, it’s shown in green,
0:33:47.2 –> 0:33:49.29 environmental risk factor.
0:33:49.29 –> 0:33:52.31 Here’s unsafe water coming in after that,
0:33:52.31 –> 0:33:54.87 but around this are a lot of things
0:33:54.87 –> 0:33:56.293 that have to do with diet.
0:33:57.53 –> 0:34:00.11 Have to do with you know, obesity,
0:34:00.11 –> 0:34:02.01 high blood pressure, right?
0:34:02.01 –> 0:34:06.82 And here’s PM2.5 pollution being comparable to all
0:34:06.82 –> 0:34:08.18 many of those other sources.
0:34:08.18 –> 0:34:11.73 So that’s been really very influential in
0:34:11.73 –> 0:34:15.09 changing people’s minds about how important air pol-
0:34:15.09 –> 0:34:18.233 is globally as a driver of global public health.
0:34:19.88 –> 0:34:21.89 I’ll mention as well that in the past year,
0:34:21.89 –> 0:34:24.72 there’s been another study come out where
0:34:24.72 –> 0:34:27.233 they looked again at the epidemiological functions
0:34:27.233 –> 0:34:31.23 that they’re using, constructed a new function,
0:34:31.23 –> 0:34:34.82 which gives us much greater number of deaths.
0:34:34.82 –> 0:34:36.903 So 8.9 is quite a bit bigger than 2.8.
0:34:38.4 –> 0:34:41.586 If they’re gonna use this function in the forthcoming
0:34:41.586 –> 0:34:44 Global Burden of Disease Assessment,
0:34:44 –> 0:34:46.85 we should expect much bigger numbers to come out of
that.
0:34:48.218 –> 0:34:49.83 Okay.
0:34:49.83 –> 0:34:52.44 How will climate change affect global air pollution
0:34:52.44 –> 0:34:55.07 and air pollution related deaths, okay?
0:34:55.07 –> 0:34:59.14 This is a figure from Arlene Fury that I collaborate
with.
0:34:59.14 –> 0:35:03.47 There’s all kinds of ways that climate change as it
occurs
0:35:03.47 –> 0:35:05.63 is expected to affect air quality.
So climate change affects meteorology. Meteorology, rainfall removes pollutants from the atmosphere, higher temperatures and more sunlight make chemical reactions happen more quickly that increases air pollution. If there’s stronger winds that can ventilate polluted region taking pollution elsewhere, that might decrease air pollution. There might be influences we expect of climate change to increase the amount of organics the trees put out. The if we look at wind blowing dust, if we look at forest fires, all of these things will be affected by climate change, okay. So there’s a lot of different pathways here, physical ways that climate change could affect air pollution. And we’re again looking at a bunch of different global models that have addressed this so what. The experiment that they ran was to hold a mission constant at present day levels and then look at 2030 experiments with future climate change versus today’s climate. And then 2100 with future climate versus today’s climate, so there’s singling out the effects of climate change. When we look over these different models, we get different answers from each model, including some models here, a few models for which, you know, depends a lot on how the spatial distribution of where air pollution is increasing because of climate change, and where it’s decreasing overlays on population, right?
So if we happen to have big increase that happens right over India, which is densely populated, that’s gonna be really important. Okay, so our multi model average year is positive, not hugely positive, and there’s big uncertainty that comes about from the spread of the different models, nonetheless, most of the models suggest increase of air pollution due to climate change, a few suggested decrease. And for PM2.5 we have fewer models that reported changes in PM2.5, but only one of them showed a small decrease. And now we have more of the models showing a big increase the magnitude here by 2100, 200 or so thousand deaths per year attributable to climate change by this mechanism. If we look at all of the ways that climate change could affect health, this actually is pretty important. Okay, you might not have guessed that climate changes effect on air pollution would be one of the important ways that it would affect health. You might think as well, right, heat stress, spread of infectious diseases, access to food and water population displaces. There’s all kinds of ways that affects health but when we’ve tried to put numbers to it, this number, you know, of deaths, puts it in the same ballpark,
as many of those other factors.

So, maybe not what you would have guessed at first, but again, because air pollution kills a lot of people that becomes important here, okay.

What are trends in air pollution related deaths in the U.S?

I’m gonna try to wrap this up somewhat quickly.

This is the work of Omar Nawaz and Yuqiang Zhang. Omar was a master student with me. Yuqiang was a PhD student and postdoc.

Omar created this nice animation for you. This is from a satellite data set looking down in North America of PM2.5 concentration.

This goes from 1998 I think it was to 2012. And we’ve taken steps in the United States to dramatically decrease air pollution and that’s sort of actually a public health success story that hasn’t been talked about quite as much as it could be.

We still have a severe air pollution problem (mumbles)

I’ll talk about in a minute. Nonetheless, we’ve taken you know, it’s mainly EPA regulations that have driven air pollution levels down.

And the effects of that are pretty dramatic when we look at it in terms of concentrations.

So we wanna look at that in terms of health as well. We’re using three different data sets, they give us concentration.
So one is this 21 year simulation using the CMAQ regional air quality model that was conducted at the EPA. So that’s pretty unique resource we’re using here. That’s sort of extended here using another data set the North American Chemical Reanalysis. This is like air pollution forecast models that archive their results, and we’re using them here. And then the satellite derived product that comes from Randall Martin’s group, he’s at the Dalhausser University in Canada, what we’re using as well as we’re using from the CDC county level population and baseline cause specific mortality rates to assess air pollution mortality, and each year, so we’re gonna do air pollution related deaths in each year, over this whole period, using this information to also account for how population other causes of death are changing. So the results that we get using our three different data sets all should have a pretty dramatic decrease this for PM2.5. The three different data sets over in the years they overlap disagree by quite a lot, unfortunately. And that’s of course, because they’re reporting different concentrations, but they all show a similar trend, okay. And that’s it’s itself sort of an interesting finding. Because we use this county level mortality rate,
we were able to then separate out the total change in death,
which is in black here with uncertainty around it,
and then the deaths that would have come about
from only the concentration change.
If we held the population and the baseline death rate
at 1990 levels, and then what the effect of population
and base, of course, population is growing over this period,
but fewer people are dying from heart attack and stroke,
which are the things that air pollution affects.
So that goes down over time.
But the bigger influence is really this concentration change.
So we can use this simulation to estimate
PM2.5 reductions since 1990 or so,
and then what the decreased death in 2010,
by about, this is using only the EPA data set,
by about 35,000 deaths or so.
Okay, we did it for ozone too, only the satellite data set
don’t apply to ozone.
So we have air pollution, ozone related deaths getting worse
than perhaps better, but quite a lot of year to year
variability here as well, okay.
And again, in this case, the baseline
death rate is going up.
So, without concentrations decreasing,
air pollution related deaths would have gone up,
but in fact, they have stayed about the same
or have gone down a little bit, okay.
This is my public service announcement since I have your attention. I've worked on different ways of talking about air pollution related deaths and how it’s important. I use the number one in 19 deaths globally from the Global Burden of Disease Assessment. For the United States, it’s about 110,000 deaths from our work about 47,000 deaths. This helps translating it to one in 25 deaths or for the United States, one in 60 or so deaths. But what I think helps more as compared against other causes of death. So in, when I talk with the public about air pollution related deaths, I try to go out of my way to say, you know, air pollution is more than all transportation accidents and all gun shootings combined. Or it’s a breast cancer plus prostate cancer, okay. I think for a lot of people that gets their attention and puts it in a different light. Why is it so important? Because at the top of this list, this is just the causes of death from the CDC is heart attack and stroke, a very large number of hundreds of thousands of deaths every year. And air pollution modifies that, air pollution affects those deaths, which means that at the end of the day, air pollution is really important here, okay. Let me skip over that. Okay, so, last question. If we slow down climate change,
what are the benefits for global air pollution and health?

This is known in the literature is that as CO-benefits so let’s say the world listen to the teenagers marching on the United Nations this week, right, got their act together and reduced greenhouse gas emissions to solve climate change.

Many of the actions that would be taken would be to shift us away from fossil fuels. We know that fossil fuel combustion is the major source of air pollution that we care about that influences our health. So there ought to be called benefits associated with that.

And there ought to be health benefits. Actually, Michelle has worked in this area too. If we look back historically at these studies, a lot of those studies were done by public health people that maybe didn’t take is a very sophisticated look at the atmospheric science part of the problem, or by economist, right?

That we’re motivated to understand, how big is this code benefit compared to the costs of reducing air pollution in the first place? When we take action to reduce emissions of greenhouse gases, that reduces greenhouse gases but also slows down air pollutant emissions, that’s good for air pollution and human health.

This is a pathway that is immediate local,
but I also told you that climate change as it occurs,
so in this context, we’re slowing down climate change,
climate change effects, air pollution.
So we’re slowing down that influence too.
So our study was the first to look at these two different pathways,
such a you could add them up together, okay.
I’ll show you some results of that study.
So again, we’re using our global atmospheric model.
In this case, I’ve worked with a team of energy economists
modelers using the what’s known as the G-Cam,
energy global energy economics model.
So in doing this, they simulate what the future would be like under, you could say a reference case
or a business as usual case without climate policy.
In their model, then they apply to a global carbon tax.
That was pretty aggressive,
aggressive enough to really actually have a big effect of slowing down climate change.
Within their model, the model is choosing the most cost effective ways of reducing greenhouse gas emissions, we were then able to see what is each of those actions have mean for air pollutant emissions,
and then put that into our global atmospheric model overlay that on the global population.
So these are global changes in global PM related deaths in the reference case,
and in the emission reduction case.
So it’s the difference between the blue and the red
That is attributable, in this case of the climate policy. We’re getting numbers that are half a million deaths or so by 2030. So immediately, we get a pretty big benefit by 2100. We’re at one and a half million deaths avoided by this climate policy. For ozone, we also get by 2100, pretty big number. This is in part because the climate policy is reducing methane and I told you when I put numbers, dollar signs associated with this I’m using here, red is using a high value of a life, blue is using a low value of a life. When I look at it in 2030, 2050, 2100, the different world regions and the global average here. So you get, you know, regions like that are densely populated, that have severe air pollution problems now, having pretty big monetize benefits that come out of this. Some regions here like Australia with a very low population, and it’s gonna be the CO-benefits are gonna be much smaller. The green shows using 13 actually different global energy economics models that all ran a similar experiment, the cost of reducing emissions per time. So this is all normalized per ton of carbon dioxide.
So, cost per ton, the solid line is the median of the 13 models and the dashed lines give you the full range of those models, okay. So that’s shown here, the benefits outweigh the cost in 2030.

Also for most world regions in the global average in 2050, by 2100, we’ve taken advantage of all the very cheap ways that we know about reducing greenhouse gas emissions and are moving up the cost curve. And there’s quite a range of estimated costs here from this point to this point, nonetheless, the CO-benefits are still pretty comfortable with that. So, we found here then that the CO-benefits are comparable to or exceed the cost of reducing emissions in the first place apart obviously, from other benefits of slowing down climate change itself. And all the reasons that you go on to that. When we looked at the CO-benefits literature, so the the entire range of CO-benefits literature is here in yellow. Dollars per time, these are studies that were done in all kinds of using different methods over a couple of decades, in all many different world regions, but most of these studies were local, or for one country. And one of the novelties of our work, we put it into this global framework, we’re now accounting for if the United States, for example, reduces emissions, that affects health.
in Europe, actually in Asia, because part of that air pollution reduction affects air quality elsewhere and benefits human health elsewhere, by putting this in a global framework, where accounting for all of those trans boundary influences, okay.

so that’s our global CO-benefits study. Yuqiang Zhang is my PhD student then did quite a lot of work to downscale that to the United States, and I’ll show you a couple of the results from that. When he did that for the United States, again, we’re similarly a global climate policy, but he ran a couple of experiments to separate out the effect of domestic within the United States emission reductions, right here versus what comes from foreign emission reduction. So when we look at PM2.5, most of the benefit is from domestic reductions that makes sense PM2.5 has a rather short lifetime in the atmosphere it doesn’t move very far from it’s source. So, most of the benefit is domestic with some influence for example, from the reductions in Mexico and Canada that effect in the United States. When we looked at the... when we looked at ozone, however, most of the emission...
actions that foreign countries took and the global reduction in methane. Okay so that was an interesting. (mumbles) Y uqiang, then looked at the health benefits associated, finding that most of the benefit for reduced PM2.5 came about from domestic reductions shown here. And most of the benefit for ozone related deaths came about from foreign reductions affecting health in the United States, great. I've covered a lot of ground today. I hope it wasn't too much for you. But I hope each of you maybe took away some nugget that you will carry with you. There was a lot of people that contributed a lot of work to this. Several graduate students over many years, I really highlighted the work of Yuqiang Zhang and Raquel Silva, over my PhD students and did a fine job doing this, and a lot of collaborators over these many studies. So thanks a lot for listening and I'm happy to take some questions. (students applauding) Yes, right here. [Female Student] I have a question about the definition of ozone layer mortality or PM2.5, related to mortality. I mean, how do you define (faintly speaking)?
Right, so what we’re doing here is we’re using results of an epidemiological study that would have related PM2.5 and ozone to mortality. And then using our model, we come up with different estimates of concentration depending on the application. And then we apply that function. So it’s the function, the epidemiological function and the epidemiological study. I should have made this clear up front more that relates PM2.5 and goes on with health. The studies that we’re using are the big cohort studies that are from the United States, largely okay. So the American Cancer Society Study. So it’s a bit of a leap of faith to say that function applies elsewhere in the world. The studies that we’re using are the big cohort studies that are from the United States, largely okay. So the American Cancer Society Study. So it’s a bit of a leap of faith to say that function applies elsewhere in the world. And we’re also in some of our applications, assuming that, that function applies throughout the whole century to come, right? We don’t know that that’s true. And we don’t know that they apply elsewhere. Now we’re getting better information about air pollution related deaths in China and India, but still not the same quality and number of participants in the study as we have for the big cohort studies in the United States. In other words, I’m not sure what else you would assume about what happens elsewhere in the world or from the future. But we should acknowledge and I didn’t say it,
but I'll say it now that there's big uncertainties and assuming that those functions apply spatially and through time like that, and hopefully that helps with your question, yeah. So particulate matter can be very diverse it's just size of a matter that you contain chromium six or (background noise drowns out other sounds) so how do you take that difference in the heterogeneity of this substance across different countries? Or is there a plan? Because you don't have the data, right? You have (faintly speaking). Well, we don’t have the epidemiological studies that tease out those relationships. I know Michelle is working in that area, and other people are as well. If we had that we if you know, give me a function, and I’ll use it. But you know, short of that, it's a real question. And from an air pollution management point of view, you know, if we knew that it was the sulfates or it was the organic carbon, we could just regulate that rather than the mass. So the limiting factor is really actually where I started off the presentation talking. It were limited by measurements of air pollution that then could be used for epidemiology, that then could divert derive a function that then we could use for this kind of application,
but, you know, we’re learning more about using those different measurements and now becoming more creative combining satellites, you could use a model, for example, to estimate the contributions of different emission sources or different chemical components to an air pollution mixture, and then do epidemiology based on the model, right? Okay, so we’re coming up with a lot of new and creative ways of approaching that question, but yet great question. Yes, please. I have a question about the function that's used for to relate air pollution with health. About where we're getting exposed like concentrations from, is it from a model or from some model measurement blending. The factor of two is more than a greater difference. And we would ideally like to see (mumbles) I mean, we’re really working to try to continue to tease out those differences.
and see if we can resolve them.

I know the satellite people have now produced a new

for PM2.5 the satellites have been really very important.

Satellites can see ground level PM2.5,

but they can’t see ground with a low ozone.

That’s one of the important distinctions here,

we didn’t have the benefit of satellite

providing information on ozone.

And they can see it with the satellites

can see it with very fine spatial resolution.

So in the PM2.5 world, you know that

it’s actually the satellite that provides a fine spatial

resolution whereas we used to fine resolution model

to do that anyways, that goes beyond your question.

But your question is a good one.

And it troubles me that it’s quite as different as it is.

But, you know, I think we need to just continue

to work on it.

See if we can work out the differences

between the different studies.

So for the 2019 (faintly speaking)

this model is gonna be adopted,

because it is a very large change.

And this is something I’ve noticed with other

updates of the GDP numbers for the same years

get updated dramatically as a result.

- Yeah.

And so depending on when you actually

access the data, you might get pretty large

in the estimates, so do you have a sense for

what’s gonna be done in the 2019 study?
Well, I know that I know what they’re doing for concentration. So they’re using a similar method for concentrations and then our ozone estimates, I mean, for PM2.5 concentrations and then our ozone estimates are gonna be used that I know well. I don’t know what risk functions they’re planning to use. And it’s a good question. But that’s, you know, they have a team of people, some of the best epidemiologists in the world reviewing the literature. So I leave that up to them to use. I try to, you know, not push the envelope there our studies are pushing the envelope just by bringing different information from different fields together. That’s why I (mumbles) so we gained nothing by using some epidemiological study that, you know, the people who really understand it, let them choose it, right? [Robert] Okay, so I think we’ll wrap it up, two announcements. So there’s lunch in the LAPH 108. And also for students who are interested in available, Jason’s gonna be having an informal discussion starting around 11:15 in room 101. So thanks again Jason. - Thank you. (students applauding) (students chattering) - Hi, I’m (speaking off mic) - Oh, hi.
Thanks a lot
(faintly speaking) or maybe already know, right?
Oh, that’s true.
Yeah, have you ever heard about that?
I saw (mumbles), I saw (mumbles), the day (mumbles).
There you go. (laughs)
but we still need to hear (faintly speaking) (laughs).
So I wanted to ask, like do you your models initially,
what sparked the question was when I saw (mumbles)
one of the earlier ones your (mumbles) over.