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Reporting Advances in Atmospheric Science from the U.S. EPA STAR Grant Program

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INSIDE:

The Climate Change Penalty on Ozone

As temperatures rise in the summer, so does harmful ozone pollution.

Though scientists have long been aware of this link, they haven't been able to describe how much dangerous pollution is associated with each degree of temperature rise.

Riddled with changing weather patterns and decreasing pollution emissions, the data has been difficult to interpret... until now.

Bryan Bloomer, a scientist at EPA's National Center for Environmental Research, has finally made sense of the mess. Using three concurrent sets of data on ozone-forming chemical emissions, ozone levels, and temperature, he was able to extrapolate the resulting increase in ozone for each degree increase in temperature.

The new metric was dubbed the "climate change penalty" by a hockey-loving colleague who recognized its similar representation of undesirable consequences.

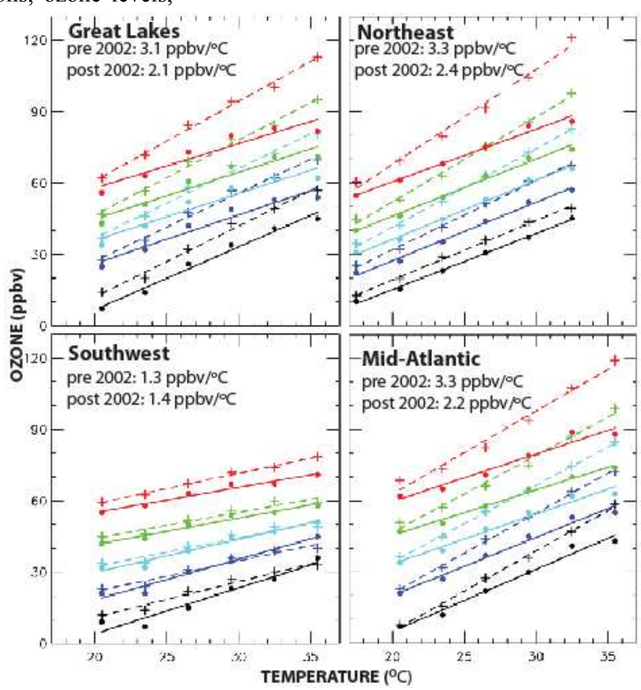
Bloomer found that for every degree of temperature rise (ºC) since 2002, the ozone penalty was 2.2 parts per billion.

For a pollutant that leads to health problems like asthma and chronic lung disease, even such a small penalty can be deadly. The 2.2 ppb increase translates to an additional 16,000 premature deaths and $2.1 billion in health expenses.

According to the Bloomer, the penalty is consistent across urban and rural areas and over a range of pollution levels, making it a critical piece of information to policymakers nationwide.

"There's an incredibly strong relationship between temperature and ozone amount regardless of whatever factors are changing," Bloomer said.

Ozone is formed in the atmosphere through a series of chemical reactions in the presence of sunlight. When the necessary chemicals (from sources like power plants) combine, they behave "like a little engine that spins off ozone air pollution," Bloomer explained.



The slopes of the lines above represent the climate change penalty for pre- & post-2002 periods for four different regions. The penalty decreases with NOx emission reductions.

As temperatures increase, the engine spins faster and its products accumulate more quickly, increasing ozone.

In 2002, the U.S. government enforced a policy to reduce emissions of ozone-producing chemicals, and as a result, ozone began to decrease.

Though there has been improvement, the decreases may have been slowed by climate change. As temperatures caused the ozone engine to accelerate, the progress spurred by the regulation was offset, Bloomer explained.

"Air pollution would have been better if it hadn't gotten warmer."

Recognizing the 2002 policy as a critical turning point, Bloomer approached the data as two distinct sets: pre and post 2002.

He found that the climate penalty was even greater before the 2002 emissions policy. With more ozone and ozone-forming chemicals in the air before the regulation, temperature rise had an even bigger impact.

This is good news for the U.S. and countries that have already taken measures to reduce ozone-forming pollutants. But it also means that the climate penalty could be particularly severe in parts of the world with unregulated or rising ozone-forming emissions.

Find out more:

Bloomer, B. et al. (2009), Observed relationships of ozone air pollution with temperature and emissions, Geophys. Res. Lett., 36, L09803, doi:10.1029/2009GL037308.

In Search of Elusive Black Carbon

What Tami Bond studies has many names.

To some, it's soot; to others, graphitic or elemental carbon.

Bond, a professor in civil engineering at the University of Illinois Urbana-Champaign, calls it "strongly light-absorbing carbonaceous particles". To the rest of us, it is simply "black carbon."

As it turns out, measuring black carbon in the atmosphere may be as difficult as defining it.

"The glasses that we use to examine the impact of carbonaceous particles on the atmosphere are fuzzy," Bond said.

"There really is no standard for measuring black carbon."

In a search of answers, Bond conducted a STAR-funded study of various black carbon measurement techniques – filtration, thermal and optical – and found that none of them is perfect.

"Each method has its strengths;" Bond said, but "each fails under different circumstances."

"If you look through an electron microscope, you can very clearly see which particles are black carbon and which aren't," Bond offered as an example. But when measuring black carbon in bulk, this method may not be representative of atmospheric particles.

Now, Bond's group is working to improve global black carbon inventories and develop methods of projecting future black carbon emissions.

In collaboration with atmospheric modelers who study particulate matter and other pollutants, Bond hopes to understand the net effect of pollution sources. But she is also studying localized sources, like individual freight trucks, that aren't meeting emission standards.

"Driving behind a truck that's not well maintained, you've had the experience of having it pull away and leaving a giant black cloud in your face.

"For black carbon, and for many other pollutants, there can be small fractions of emitters that produce a lot of the emissions," Bond explained.

Several major assessment reports from international organizations like the Arctic council and the United Nations Environment Programme are scheduled to come out over the next year. A major assessment effort within the EPA is ongoing and will be delivered to Congress by April of 2011.

For Bond though, the mission is to uncover the best ways to measure and understand black carbon. Time will tell whether it's mission: impossible. □

Find out more:

Tami Bond's Black Carbon Research Project

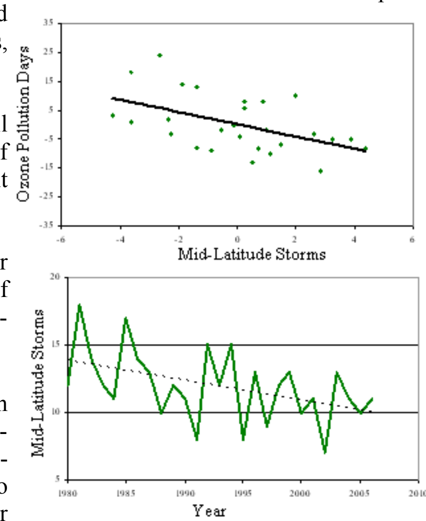
Clear Skies & Fewer Storms Mean More Ozone Pollution

Next time it rains, breathe deep. A recent study reports that rain storms and ozone may be inversely related.

In a 2008 Harvard study, Eric Leibensperger analyzed the number of days when ozone concentrations exceeded national standards and the number of non-tropical storms in the eastern U.S. over a 27 year period. He found that the more storms there were in a given year, the fewer days ozone pollution reached dangerous levels.

Leibensperger looked at non-tropical storms that travel eastward across North America. Cold fronts associated with these storms flush the air of pollutants, leaving cleaner air in their wake.

But climate change is altering the number of storms in certain regions. Data shows that the number of non-tropical



Top: Relationship between annual frequency of mid-latitude storms and ozone pollution days, 1980-2006 (de-trended). Bottom: Decrease in average annual number of storms, 1980-2006.

storms has been on the decline since 1980.

Without the natural flush of rain, ozone can stagnate and rise to dangerous levels, causing asthma, chronic lung disease, and other serious health problems.

Because of climat change, measures taken by the U.S. to reduce ozone pollution aren't working as quickly as anticipated.

According to Leibensperger's research, the average number of high ozone pollution days per year in the Northeast should have reached zero by 2001. But in 2006, there was still a six-days-per-year average. Some regions in the eastern U.S. had as many as 10 high ozone days.

Climate change continues to erode the success of ozone mitigation programs. Leibensperger's group found that the decrease in non-tropical storms since 1980 has offset half of the air quality gains policy makers originally anticipated.

Future research will explore whether climate change has similar affects on other air pollutants, like particulate matter. □

Read the full paper:

Leibensperger EM, et al. (2008). Sensitivity of US air quality to mid-latitude cyclone frequency and implications of 1980-2006 climate change. Atmos. Chem & Physics. 8: 7075-7086.

Air Quality & the Endangerment Finding

After years of scientific research, court cases, and policy efforts, the EPA now officially states that greenhouse gases are a threat to public health.

A major reason? Climate's impact on air quality.

The landmark declaration, called the Endangerment Finding, was signed in December by EPA Administrator Lisa Jackson and includes several citations of EPA and STAR research on air quality.

While a large body of scientific evidence supports the Finding, the studies linking climate change to air quality play a key role. These studies include work from scientists within EPA's Office of Research and Development as well as STAR funded researchers who have emerged as leaders in the field.

The group of scientific results was reviewed by a STAR researcher and an EPA scientist in a 2009 *Atmospheric Environment* article.

According to the article, climate change will prevent summertime ozone levels from decreasing as much as they otherwise would.

Practically speaking, climate change will make it much more difficult for states to meet ozone pollution standards, posing potentially large economic burdens on states already struggling to do so. The paper also suggests that polluted, urban areas will suffer the greatest impacts of climate on air quality.

Because poor air quality is known to have significant effects on respiratory and cardiovascular health, these studies also explain how climate change can directly impact people.

While the Endangerment Finding does not, in itself, impose restrictions on industry or polluting entities, it does provide the required and long sought-after justification for future greenhouse gas emissions standards. Such standards were proposed by EPA in September, but could not move forward without evidence that greenhouse gases are directly harmful to people.

The Endangerment Finding is a milestone. It has opened the door for future policies to curb greenhouse gases and protect public health. □

Read more:

General information on the Endangerment Finding: http://www.epa.gov/climatechange/endangerment.html

Jacob and Winner, 2009. Effects of climate Change on Air Quality, Atmos. Environ., 43, 51-63, 2009

Xin-Zhong Liang: A Model Scientist

Over 25 years ago, Xin-Zhong Liang shut himself in a room with a dozen computer monitors. He emerged two weeks later and 15 pounds lighter.

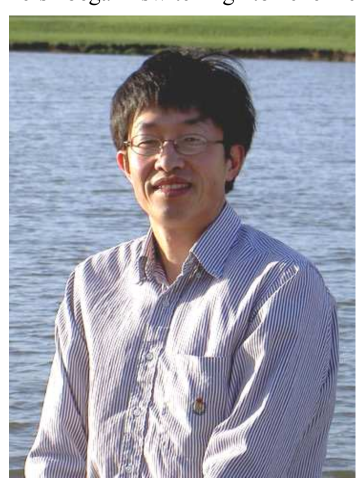
Disregarding food and sleep, Liang took drastic measures to model environmental processes, which, without the processing power of today's computers, was an arduous task.

Now a senior scientist at the Illinois State Water Survey and adjunct professor in the Department of Atmospheric Sciences at the University of Illinois, Liang, 46, builds (more efficient) computer models that predict climate and changes in the environment. His work projects the affects of climate change on future ozone and particulate matter concentrations, weather patterns, water resources, invasive species, crop yields and pollution transport.

Liang is well-suited for numerical modeling. He is focused, precise and apparently starved for information—more so than food.

"Sometimes I stay in the office until 10 or 11 at night," he admitted. "I don't even notice that I'm hungry."

Liang grew up in rural Wenling, China, frequently swimming in farm-side ponds. Farmers used the pond's silt to fertilize their crops. But as Liang grew up and farmers began switching to chemical



Xin-Zhong Liang, senior scientist at the Illinois State Water Survey

fertilizers, he noticed the streams nearby grow sullied before his eyes. He realized that the ponds must have regulated environmental processes.

Liang's experience inspired him to pursue environmental issues. While his STAR-funded work focuses on regional modeling for the U.S., he also maintains a connection to China, collaborating with scientists there to raise environmental standards.

Liang takes the unique approach of building models by expanding inward—a process called global-to-regional downscaling. He first scales models of the entire planet, then fills in details to include smaller regions like the American Midwest.

"There is no single scheme or numerical model that does the right job," Liang said.

So he works on models that can be adapted with regional data like the permeability of local bedrock. To maximize accuracy, Liang seeks to incorporate, "each cotton or soybean, how they grow, how they are blooming... everything."

He says the end result would be a "fully coupled earth system model" that can capture "land use, climate, emissions, all these global changes and their consequences."

When Liang began modeling, he used punch-card computers. Now, as technology develops, so do his models— gaining whatever accuracy and complexity technology allows.

"I never feel that the computer is enough," Liang admitted. "I still keep building the models bigger."

"What is really missing right now is the social branch," Liang said, explaining that he hopes to some day incorporate economics and human behavior into his climate models.

For now, he is transitioning from atmospheric modeling to water modeling. Liang's latest STAR research focuses on climate change, water quality and the nitrogen cycle.

Liang's ultimate goal is to develop a model that could support decision making during natural emergencies like hurricanes and wildfires. In his fantasy, the models would combine satellite data and human intelligence to determine the best evacuation routes or firefighting strategies in real-time.

"This is my dream," Liang said. □

Climate Change Impacts on Air Pollution & Health

Through a recent cooperative agreement between Georgia Tech scientists and the EPA STAR program, scientists have found that climate change may lead to more sever cases of asthma, bronchitis and heart disease.

Lead author Efthimios Tagaris and collaborators used computer models to estimate the concentrations of two major air pollutants, particulate matter (PM) and ozone, in a projected 2050 climate. They then determined the pollution-related health effects, like deaths and emergency room visits, that would result.

According to their research, health effects will increase in two-thirds of U.S. states. And of the two pollutants studied, PM will likely be the greater health hazard.

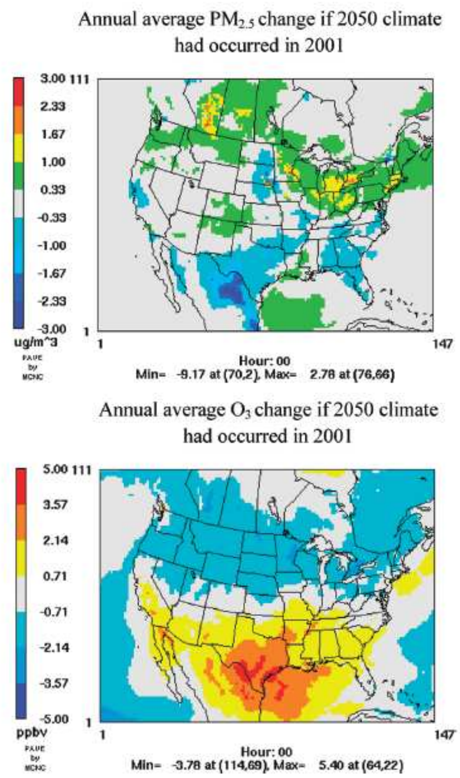
Tagaris ran computer models which kept most variables – population, air pollution sources, human activity, pollution control methods – fixed at 2001 levels. This ensured that any observed change in health effects would be a result of climate change. To get data on climate in 2050, the scientists used predictions from the Intergovernmental Panel on Climate Change.

In compiling the information by state, they found varied effects in different regions. Particulate matter concentrations, for example, increased in the Northeast and Great Lakes regions but decreased in other parts of the country. Ozone concentrations increased in southern states but decreased in the northern states.
Nationwide, they predicted an additional 4,000 premature deaths from particulate matter and nearly 300 from ozone**.** Urban areas also showed more severe pollution and resulting health problems than sparsely populated areas.

Tagaris' research suggests a growing need for region-specific air quality management strategies that incorporate climate change predictions. □

Find out more:

Efthimios Tagaris, et al. (2009), [Potential Impact of Climate Change on Air Pollution-Related Human Health Effects](), Environmental Science & Technology 43 (13), 4979-4988.



Annual $PM_{2.5}$ and ozone concentrations changes in future climate (i.e., 2050) compared to 2001 climate.

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