MASSACHUSETTS INSTITUTE OF TECHNOLOGY

MIT JOINT PROGRAM ON THE
Science & Policy of Global Change

Global Changes

Fall 2011 | In this Issue

Discovering new interactions, impacts, and feedbacks among natural and human climate systems

Objectively assessing uncertainty and risk in economic and climate projections

Critically and quantitatively analyzing mitigation, management, and energy policy proposals

Understanding connections between climate change and other environmental policy issues

Improving methods to model, monitor, and verify greenhouse gas emissions and climate impacts

Integrating natural and social science to produce analyses relevant to climate and energy policy debates

In This Issue:

Advances in urban air pollution modeling techniques

Evaluating costs and benefits of renewable energy sources

Climate adaptation in developed versus developing countries

Introducing The China Energy and Climate Project (CECP) at MIT

In collaboration with Tsinghua University, MIT launches a new research project to analyze the impact of China's existing and proposed energy and climate policies

Multiple forecasts suggest that rapidly developing nations like China will be responsible for most of the growth in CO_2 emissions over the next 50 years. This expectation is the driving force behind the formation of a new project involving researchers from MIT and China, known as the China Energy and Climate Project (CECP).

The China Energy and Climate Project will involve close collaboration and personnel exchange between the Institute for Energy, Environment, and Economy at Tsinghua University in Beijing, China and the MIT Joint Program on the Science and Policy of Global Change. In collaboration with the MIT Energy Initiative, the five-year project is based out of MIT and directed by Dr. Valerie Karplus, a recent Doctoral graduate from MIT's Engineering Systems Division (June 2011). Dr. John Reilly, co-director of the MIT Joint Program on the Science and Policy of Global Change and senior lecturer in the Sloan School of Management, will be a principal investigator.

The goal of the CECP is to analyze the impact of existing and proposed energy and climate policies in China on technology, energy use, the environment, and economic welfare by applying—and where necessary, developing—both quantitative and qualitative analysis tools.

The development and application of such new analysis tools will include both national and regional energy-economic models of China. Growing out of the MIT Joint Program's Emissions Prediction and Policy Analysis (EPPA) model, these new tools will be informed by three major components.

First, researchers will study the behaviors and trends that drive micro-level decisions made by household and firms to better understand supply and demand within energy-intensive sectors. Second, the researchers will analyze specific technology prospects, including electric vehicles, advanced fuels, and alternative sources of electricity, to determine China's technology potential. Finally, current and proposed climate and energy policies in China will be evaluated for environmental and economic impact. These evaluations will be conducted primarily through the use of the models developed for the project, which will be based on similar methods employed in the MIT Joint Program over the last 20 years.

清华–麻省理工 能源和气候变化模型研究项目

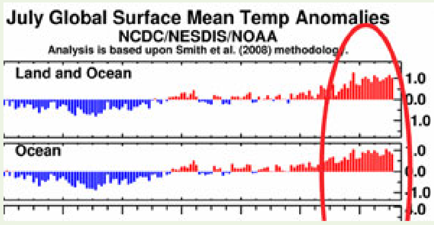
Tsinghua-MIT Program on Energy and Climate Change Modeling

"We are building a strong transpacific research team that brings expertise in economics, engineering, and public policy to this exciting new project," says Karplus. "Both sides are eager to get started, to learn from each other, and to produce rigorous analysis on important policy questions."

The research carried out on MIT's side of the project is funded by founding sponsors Eni, ICF International, and Shell. The project will present its findings at an annual meeting in Beijing to influential members of the academic, industry, and policy communities in China. The project will inform rigorous, transparent analysis of climate and energy policy options in China and its global implications.

Launch of Joint Program Sponsor's Webinar Series

September 15, 2011



The first Joint Program sponsor's webinar took place on September 15th. Professor Ron Prinn, Joint Program Co-Director and Professor of Atmospheric Science, spoke on "Hot Issues in Climate Science: (a) Recent Trends: weather or climate change, & why? (b) Probabilistic climate forecasts & potential risks".

For those sponsors who were unable to attend the live webinar, a video of the event is posted in the new sponsors-only section of the webpage. The video, and a pdf of Dr. Prinn's slides, may be viewed under the "Archived Webinars" tab here: http://globalchange.mit.edu/sponsors/sponsoronly/webinars.html

The next webinar will be:

November 10, 2011
10:30 a.m. - 12:00 p.m. EDT
Presenter: Dr. John M. Reilly
Joint Program Co-Director,
Senior Lecturer Sloan School of Management
Topic: Energy, Environment, & Economic Outlook

More information will follow in e-mailed invitations. We hope you will be able to attend!

A new look for the Joint Program

After 20 years, the Joint Program is getting a new logo and a fresh look. Keep an eye out for changes in the design of our program brochure, report covers, and newsletters (like this one!). In addition, we are in the process of revitalizing our website, with several new features to better serve our visitors.

XXXIII MIT Global Change Forum

March 28-30, 2012

Arlington, VA/ Washington DC area

Evaluating Progress on the Climate Front

Forum attendance is by invitation only.
More information to follow.

Sponsors-Only Website

http://globalchange.mit.edu/sponsors/sponsorsonly/

A special, and private, section of the MIT Joint Program website has been created with member sponsor needs in mind. Our intention is for this to be a place where we provide our sponsor members with membership-only privileges, providing added value to membership. We hope this resource repository offers the opportunity to provide feedback, and serves as a location for dissemination of timely and interesting information.

The website may be accessed through the link above. However, as we redesign our website and move to a new web format, this area will require a password to access pages in the future. Information on passwords will be distributed to sponsor members through e-mail.

Students Coming and Going

New students:
Amanda Giang (N. Selin)
Jimmy Gasore (R. Prinn)
Ioanna Karkatsouli (S. Paltsev)
Bryan Palmintier (M. Webster)
David Plotkin (M. Greenstone)
Bilhuda Rasheed (A. Schlosser)
Daniel Rothernberg (C. Wang)
Leah Stokes (N. Selin)
Berk Ustun (M. Webster)

Graduated students:
Suhail Ahmad
Sirein Awadalla
Jonathan Baker
Caroline Brun
Caleb Waugh
Chris Gillespie

Personnel Changes

Alex Avramov was hired as a new postdoc, working on aerosol modeling

Elodie Blanc, a former visiting PhD student, is now a postdoc working on agricultural impacts

Yongxia Cai was promoted to Research Scientist

Allison Crimmins (Communications Officer) is leaving MIT to work with the EPA

Robens Joseph was promoted to Financial Officer

Valerie Karplus graduated from PhD student to Project Director, China Energy and Climate Project

Eunjee Lee graduated from PhD student to postdoc

Helen MacIntyre was hired as a new postdoc, working on aerosol modeling

Erwan Monier was promoted to Research Scientist

Kyung-Min Nam graduated from PhD student to postdoc

Sergey Paltsev was promoted to Assistant Director for Economic Research of the Joint Program

Sebastian Rausch was promoted to Project Director, US Regional Energy and Environment

Niven Winchester was hired as Environmental Energy Economist

Qianlai Zhuang is visiting from Purdue University

Dr. Susan Solomon joins MIT

January 1, 2012

The Joint Program welcomes Dr. Susan Solomon to MIT! Dr. Solomon will join the Earth, Atmospheric, and Planetary Science faculty as Professor of Atmospheric Chemistry and Climate Science effective January 1, 2012.

Dr. Solomon did seminal work on the heterogeneous chemistry that underlies ozone depletion, the effect of ozone depletion on climate change. and the virtual irreversibility of CO_2-induced climate change. She also co-led Working Group I of the most recent report of the Intergovernmental Panel on Climate Change (IPCC), which won the 2007 Nobel Peace Prize.

Looking forward, Dr. Solomon plans to begin new interdisciplinary research, initially focusing on how temporal and spatial scales of environmental phenomena influence human decision making. We look forward to many future collaborations!

New Research Projects from Federal Grants

Integrated Assessment of Greenhouse Gases and Climate Impacts
Project Leaders: John Reilly and Chien Wang

The MIT Integrated Global Systems Model (IGSM) framework will be used to provide an integrated assessment of greenhouse gases with a focus on potential impacts and adaptations within the United States. The framework includes modules that have been developed or are under development to examine multiple environmental effects on human health, agriculture and forestry, water resources (quantity and quality), sea level rise and coastal damage, and energy demand and infrastructure. In collaboration with the Marine Biological Laboratory Ecosystems Center.

Source: U.S. Environmental Protection Agency, Office of Air and Radiation

A Modeling Analysis of the Impact of Aerosols from Combustion Sources on Actinic Fluxes and Photolysis Rates Constrained by Aircraft and Satellite Data
Project Leaders: Chien Wang and Matthew Alvarado

The project will quantify the impact of combustion aerosols on tropospheric chemistry. Carbonaceous combustion aerosols commonly come from anthropogenic activities and biomass burning. Via improved atmospheric transport models, researchers will investigate the impact of combustion aerosols on global actinic flux and photochemistry, with evaluation by comparisons with in-situ observations. In collaboration with Atmospheric and Environmental Research, Inc. and University of Maryland, Baltimore County.

Source: NASA Earth Sciences Division - Atmospheric Composition: Modeling and Analysis Program

Decision making under coupled multi-timescale uncertainty: Advanced electric power systems planning
Project Leaders: Mort Webster and Youssef Marzouk

The objective of this research is to develop improved planning tools for electric power systems such that constraints on how electricity generators operate are accounted for in long-term investment planning for generation technologies. The structure of operations and investment will be exploited to develop efficient methods for optimizing the full system, accounting for uncertainty in demand, renewable generation, fuel prices, and possible environmental regulations.

Source: NSF - Division of Electrical, Communications and Cyber Systems; Energy Power and Adaptive Systems Program

Integrated Assessment of Transportation-Related Policies on Greenhouse Gases, Land Use Change, and Other Economy-Wide Impacts
Project Leader: Sergey Paltsev

Using the MIT Integrated Global Systems Model (IGSM) framework, research will quantify the implications of transportation-related policies, including impacts on land use, fuel use, greenhouse gas emissions, changes in the energy sector, and other economy-wide impacts. The framework will be used to assess interactions between agricultural, forestry, livestock, and energy sectors. Some of the policies to be evaluated include increased renewable fuel usage, improved fuel efficiency of cars and light trucks, regulatory policies in non-transport sectors, and sectoral and economy-wide carbon policies.

Source: U.S. Environmental Protection Agency, Office of Air and Radiation

Collaborative Research: Quantifying Climate Feedbacks of the Terrestrial Biosphere under Thawing Permafrost Conditions in the Arctic
Project Leaders: Adam Schlosser and Qianlai Zhuang

The project will quantify the potential for threshold changes in natural emission rates of trace gases, particularly methane and carbon dioxide, from pan-arctic terrestrial systems under anthropogenically-forced climate warming. Polar amplification of global climate warming will induce widespread thaw and degradation of the permafrost, and would thus cause substantial changes to the landscape of wetlands and lakes across the Arctic. The research will advance a fully coupled earth system based on a suite of models of surface and groundwater hydrology, permafrost, carbon and methane dynamics, atmospheric chemistry and climate, ocean chemistry and circulation and the global economy. In collaboration with Purdue University and Marine Biological Laboratory.

Source: DOE Office of Biological and Environmental Research, Climate & Environmental Sciences Division, Earth System Model Development Program

Recently Released Reports and Reprints

Report 206: Process modeling of global soil nitrous oxide emissions

Report 205: Quantifying the likelihood of regional climate change: A hybridized approach

Report 204: Implementation of a cloud radiative adjustment method to change the climate sensitivity of CAM3

Report 201: Russia's natural gas export potential up to 2050

Reprint 2011-8: Learning through the international joint venture: lessons from the experience of China's automotive sector

Reprint 2011-6: Climatology and trends in the forcing of the stratospheric ozone transport

Reprint 2011-4: An analysis of US greenhouse gas cap-and-trade proposals using a forward-looking economic model

Upcoming Publications

Forthcoming Joint Program Reports

Characterization of wind power resource in the United States and its intermittency

A global 3-D model to simulate long-range transport of polycyclic aromatic hydrocarbons: Evaluation and analysis

Impact of air quality model resolution on health effects uncertainty: Implications for regulatory procedures

The influence of shale gas on U.S. energy and environmental policy

Stocks & shocks: A clarification in the debate over price vs. quantity controls for greenhouse gases

Pending Publications

Science and strategies to reduce mercury risks: A critical review

Marginal abatement costs and marginal welfare costs for greenhouse gas emissions reductions: Results from the EPPA model

Atmospheric chemistry, modeling and biogeochemistry of mercury

Nitrogen effect on carbon-water coupling in forests, grasslands, and shrublands in the arid western U.S.

Report 203: Global Aerosol Health Impacts: Quantifying Uncertainties

On air quality and health impacts

Air quality is a global concern— but how well do we understand the health and economic burdens imposed by air pollution worldwide? A recent report from the MIT Joint Program on the Science and Policy of Global addresses this question for one category of air pollutants. The answer: not very well.

The MIT report examines atmospheric fine particulate matter smaller than 2.5 µm, or $PM_{2.5}$. $PM_{2.5}$ is harmful to human health, leading to heart disease, lung cancer, and death. Therefore, assessing population exposure to and damages from $PM_{2.5}$ is important for policymakers working to regulate emissions. But efforts to quantify the impacts of $PM_{2.5}$ have been characterized by large uncertainty ranges.

To figure out the global health and economic burden (welfare loss) of $PM_{2.5}$, and therefore the benefits of any policy that would regulate emissions, you need several pieces of information. First, on the atmospheric science side, you need to know how much $PM_{2.5}$ is in the atmosphere and how much people are exposed to over time. Then, on the damage quantification side, you need to determine the health impacts resulting from exposure and quantify the economic damages resulting from those impacts. At every step along this causal chain, uncertainties are introduced (see figure on right).

The MIT researchers assessed the global-scale uncertainties contributed by air quality information (the atmospheric side of the equation) and compared that to the uncertainties in the health and economic estimations (the damage quantification side of the equation) to better understand the relative importance of errors in calculating $PM_{2.5}$ impacts.

One of the challenges of estimating exposure is that only a small fraction of people live in areas constrained by measurement data. In fact, the study found that ground-based $PM_{2.5}$ measurement data represents only 10% of the global population. Using two different atmospheric models (GEOS-Chem and MIT/NCAR CAM3) and information from a satellite product (MODIS and MISR), the study showed large differences in population-weighted $PM_{2.5}$ concentration estimates, especially outside data-constrained regions.

A large fraction of this variation between concentration estimates is the result of dust. Aerosols like $PM_{2.5}$ are made up of multiple components, such as sulfates, organic carbon, black carbon, nitrates, sea salt, and dust. But the fraction of these different components that make up the $PM_{2.5}$ category can be different depending on geography. The researchers showed that the specific cocktail of $PM_{2.5}$ components that people are exposed to in the US is very different from other parts of the world. Specifically, greater than 30% of the $PM_{2.5}$ that global populations are exposed to is dust— in the US, 5% comes from dust. Because epidemiological studies relating $PM_{2.5}$ to toxicity have been conducted in the US, based on the types of aerosol components US populations are exposed to,

Atmospheric fine particulate matter <2.5 µm ($PM_{2.5}$) can cause cardiovasculatory and respiratory damages and mortalities. Assessing population exposure to and damages from $PM_{2.5}$ is important for policy.

the response functions that relate exposure to health impacts may need to be revised to be applicable globally.

Overall, the researchers found that the variation in the atmospheric concentration estimates contributed a comparable amount of uncertainty in estimating $PM_{2.5}$ impacts as the variation in health and economic impact estimates. In other words, when calculating the impacts of $PM_{2.5}$, researchers are as limited by atmospheric science uncertainties as they are by damage quantification uncertainties.

So, with these uncertainty ranges in mind, what are the present-day impacts of $PM_{2.5}$? Using the Emission Prediction and Policy Analysis Heath Effects Model (EPPA-HE), the MIT researchers calculated global welfare costs to be between US$120-510 billion annually, with a mean estimate of US$280 billion. This is equivalent to a loss of 0.3-1.1% in 2005 global welfare. They also estimated 1.3 million annual mortalities associated with $PM_{2.5}$ (with a range of 630,000–2.1million). To better constrain these large uncertainty ranges, the authors suggest increasing the measurement network coverage and further evaluating and comparing model evaluations of highly-populated regions in developing countries.

[Selin, N.E., S. Paltsev, C. Wang, A. van Donkelaar, and R. V. Martin. August 2011]

Atmospheric Science

Air Quality

$PM_{2.5}$ estimates from two atmospheric models (GEOS-Chem and MIT/NCAR CAM3) and one satellite product (MODIS and MISR)

Concentration of $PM_{2.5}$ in the atmosphere + **Exposure (population-weighted)**

Large differences in population-weighted $PM_{2.5}$ concentration estimates come from 1) Different assumptions about emissions and atmospheric processing, 2) Regional differences in the chemical components that make up total aerosol concentration.

Ground-based $PM_{2.5}$ measurement data represents only 10% of the global population. Using different concentration estimates leads to large differences in population-weighted $PM_{2.5}$, especially outside data constrained areas. A large fraction of this variability resulted from dust, which is poorly constrained.

Range of Variability

X

≈

Damage Quantification

Health and Economics

Air pollution health impact estimates and values from MIT Emissions Prediction and Policy Analysis Health Effects Model (EPPA-HE)

Epidemiological concentration-response function + **Economic costs of air pollution health impacts**

EPPA-HE calculates health impacts including morbidities (hospital admissions, respiratory and cardiovascular disease) and mortalities from acute and chronic exposure, in cases per μg m^{-3} of $PM_{2.5}$, based on concentration-response values from existing literature surveys.

EPAA-HE measures consumption, labor, and leisure losses from morbidity and mortalities, including cumulative losses from premature death. Values for morbidities reflect both treatment costs and willingness-to-pay to avoid damages.

Range of Variability

=

Potential benefit of reducing $PM_{2.5}$

Global Health and Economic Burden (welfare loss) of $PM_{2.5}$

Global welfare costs of present-day $PM_{2.5}$ ranged from US$120-510 billion annually, with a median of US$280 billion, or 0.3- 1.1% of 2005 global welfare. 1.3 million annual mortalities are estimated to be associated with global $PM_{2.5}$.

Reprint 2011-5: Food, Fuel, Forests, and the Pricing of Ecosystem Services

Valuing the trees through the forest: Competing demands for food, fuels, and forests

Reprinted from MIT News (9.8.2011)

How do you value an ecosystem? Putting a dollar value on natural systems like forests has long beset economists.

Concern about degradation of natural resources has led to the concept of "ecosystem services." The intent is to identify more fully what environmental economists would refer to as "use values" of ecosystems: concrete goods and services that have value, albeit perhaps unrecognized, to the market economy.

Forests provide "non-use values", such as the pleasure of knowing that a natural system exists, and recreational values, like hunting, fishing, and wildlife viewing. But recently, ecologists have also sought to value a broader set of "ecosystem services", or the goods and services that ecosystems provide to a market economy.

Ecosystem services related to land include conventional food and forest products, as well as the potential to produce biofuels. But ecosystems also have the ability to store carbon. If a price on carbon were established, an incentive to enhance carbon storage would be created. This new ecosystem service would need to be balanced against conventional food, forestry, and biofuels production services. As the number of ecosystem services expands and are fully priced in a market, the demand for land naturally increases.

Researchers from the MIT Joint Program on the Science and Policy of Global Change have used an economic model to explicitly represent recreation value of ecosystems and their carbon storage value. The study examines how demand for ecosystem services will affect land use, food prices, and the prospects for biofuels production.

Their study found that growth in demand for biofuels increases when a carbon tax is implemented, leading to increases in CO_2 emissions from the conversion of forests to cropland. However, if that carbon tax also includes emissions from land use change, the resulting economic incentive is enough to avoid deforestation. And, if a tradeable credit program to incentivize CO_2 sequestration on land is implemented, significant reforestation occurs, such that land use becomes a large net sink for CO_2.

This is a surprising result, as land use emissions currently make up about 20% of total emissions. But, with carbon taxes and a tradeable credit program, land use would mitigate emissions by storing carbon in forests and replacing fossil fuels with biofuels. In fact, the analysis shows that if carbon storage were credited, land conversion would eventually store as much as one third of the entire global energy emissions over the coming century.

Unfortunately, it's not that simple— such policies would imply some difficult tradeoffs. In the scenario with full carbon pricing, substantial reforestation and biofuels production occurs, but at the expense of conventional agricultural products. The two new non-food demands for land cause commodity prices to increase, especially impacting livestock prices. The livestock sector is particularly affected because both the rental prices for grazing land and the price of grains used to feed livestock rise. As food prices rise, poor consumers will be considerably affected and may suffer.

"Since conventional agricultural goods are priced in markets, the higher [food] prices projected are efficient in the sense that they reflect the marginal value of storing carbon that would be lost if more land were devoted to food production," explains John Reilly, co-director of the MIT Joint Program and co-author of the study. He adds "However, the market values do not take into account equity considerations, and so in the absence of food programs worldwide such higher prices would place a disproportionate burden on lower income people."

Some of the resulting increase in food prices may be offset by future agricultural technology. But even with such technologies, increasing food prices would still be a substantial departure from the historical trend of falling food prices. As new demands for land stem from an expanded view of ecosystem services, special attention will be needed to counteract the impacts on development and food security.

"It is a dilemma where climate change itself may have negative consequences for food production but extensive reforestation to limit climate change may also squeeze food production by limiting the land available for conventional agriculture. Thrown on top is a demand for land for biofuels production that could put further pressure on food prices," says Reilly. "The results are a cautionary tale in embracing efficient market solutions in a world where there are not ready mechanisms to deal with inequitable outcomes."

[Gurgel, A., T. Cronin, J. Reilly, S. Paltsev, D. Kicklighter, and J. Melillo. American Journal of Agricultural Economics, 93(2): January, 2011]

Reprint 2011-7: Potential Climatic Impacts and Reliability of Large-scale Offshore Wind Farms

Model improvements help to explore environmental impacts of offshore wind farms

Recent interests in renewable energy technologies have drawn attention to wind power as an alternative to fossil-fuel based sources. But to meet even a relatively small fraction of the world's predicted energy demand in 2100, several million or more wind turbines would need to be deployed globally. Such a massive deployment could carry its own suite of environmental impacts.

A recent study from the MIT Joint Program on the Science and Policy of Global Change examines the impacts of large-scale offshore wind turbines. The research builds upon a previous study (MIT News, 3/12/2010), which focused primarily on land-based wind turbine deployment.

If wind power is going to meet 20% of our predicted energy needs in 2100, millions of wind turbines must be installed around the globe. Modelling performed by researchers at Massachusetts Institute of Technology, US, has shown that these vast wind farms, if installed in offshore regions, could reduce the temperature of the lower atmosphere above the site by 1 °C.

Nadya Anscombe, Environmental Research Letters News, 8/1/2011.

In that study, Senior Research Scientist Chien Wang, of the Center for Global Change Science, and Ron Prinn, TEPCO Professor of Atmospheric Science, found that a deployment of land-based wind turbines large enough to meet 10% of predicted world energy needs in 2100 could lead to significant localized surface warming. "Our effort was the first assessment of the climate effects associated with large-scale deployment of wind turbines using a coupled atmosphere-ocean model," explained Wang. "[The study] questions current estimations of wind power availability, which haven't considered the effects of installed wind turbines."

The same researchers, equipped with a recently updated three-dimensional atmospheric climate model, are now focusing their sights on offshore wind turbine deployment. In this new study, the model's spatial resolution was increased and six additional simulations were modeled to assess potential environmental impacts.

In contrast to the previous land-based results, the MIT researchers found temperatures in regions where the offshore wind farms were installed decreased. This local surface cooling effect exceeded 1 degree Celsius in high latitude sites and areas with the highest density of turbines installed. This cooling is primarily due to enhanced evaporation from the sea surface to the lower atmosphere, driven by an increase in turbulent mixing of air currents caused by the wind turbines.

Given the significant changes in local temperatures caused by the wind turbines, the authors expected to see impacts on temperature, clouds, precipitation, and large-scale circulation beyond the areas where the turbines were installed. However, the study found that these non-local impacts were relatively small compared to those caused by land-based installations.

What the researchers did find was significant seasonal wind variations. This variability in available wind power highlights an intermittency issue for potential electricity-generating and distributing systems over several major offshore sites. "Our results raise several serious issues for such an alternative energy technology, including its reliability," says Wang. This issue would need to be carefully addressed to manage power transmission, storage, and backup power facilities for off-shore wind farms

[Wang, C., and R.G. Prinn. Environmental Research Letters, 6(2): June 2011]

Reprint 2011-11 and 2011-13: The Impact of Detailed Urban-Scale Processing on the Composition, Distribution, and Radiative Forcing of Anthropogenic Aerosols

Reprinted from MIT News (8.29.2011)

A new way to model urban air pollution

Urban regions account for an ever increasing fraction of Earth's population, and are consequently an ever increasing source of air pollutants. These pollutants include anthropogenic aerosols, which have important climate and health implications.

But modeling aerosol emissions from urban areas is difficult due to the detailed temporal and spatial scales required. Thus, urban areas significantly contribute to the overall uncertainty and variability in global atmospheric model predictions of aerosol and pollutant distribution.

To address these uncertainties, researchers from the MIT Joint Program on the Science and Policy of Global Change set out to see if they could better model aerosol emissions and distribution from urban regions. To accurately model urban areas, factors like the amount and distribution of emissions, the meteorological and geographical properties of the region, and the chemical and physical processing of emissions over time would need to be considered on spatial and temporal scales much smaller than global models. Previously, modelers have attempted to account for urban aerosol emissions by using a correction factor, which diluted total aerosol emissions across global model grid cells. This dilution method, however, does not capture the heterogeneity of urban and non-urban areas within each grid cell.

Detailed urban-scale processing has not been included in global chemical transport models due to large computational demands.

Instead, the MIT researchers developed a new detailed air quality model, using meteorological and emissions data from 16 representative urban areas. This urban processing model examined seven different types of aerosols of different sizes and composition, and modeled a total of 251 urban areas, including 91 from China, 36 from India, 50 from developed nations (Australia, Canada, EU, Japan, Singapore, South Korea, US) and 74 from developing nations. The urban processing model was then included into a larger global model that simulates atmospheric chemistry and transport at regional to global scales. Researchers compared the predicted atmospheric aerosol concentrations using this new method with results from the dilution method.

"Not only are we the first group to successfully incorporate an urban-scale chemical processing model into a 3-dimensional global model," explains Dr. Jason Cohen, the lead author on the report, "but our results resolve important processes which the rest of the modeling community still neglects to include".

The researchers found that the urban processing model predicted a lower concentration of atmospheric aerosols than the dilution method, particularly in the Northern Hemisphere and in the summer season. In addition, the urban processing model showed increased concentrations of primary aerosols, like black carbon and organic carbon, and decreased concentrations of secondary aerosols, like sulfates. Thus excluding the urban processing model could lead to an overestimation of some aerosols and an underestimation of others.

The reason these biases exist in the dilution method is that urban areas tend to be more efficient at oxidizing and removing substances like black carbon and organic carbon from the atmosphere— not taking this into consideration leads to an overestimation of the concentration of these species. Because these aerosol species are oxidized, generation of the secondary aerosol species actually increase in urban areas— not taking this into consideration leads to an underestimation of the concentration of those species.

Aerosols tend to cause negative radiative forcing. In other words, they have an overall "cooling effect" on the global climate. But using the urban processing method instead of the dilution method demonstrated an overall smaller concentration of aerosols in the atmosphere. Thus the detailed urban processing model predicts significantly less negative aerosol radiative forcing (less cooling) than the dilution method.

"We are continuing this effort, looking at the long-term climate effects of using detailed urban processing, such as how average surface temperature, precipitation, and cloud cover will be impacted," says Cohen. "We hope that as we continue to look into the impacts of this new methodology and continue to learn more about the mistakes that the dilution simplification have led to, that others in the climate modeling community will adopt and use our new standard."

[Cohen, J.B., R.G. Prinn and C. Wang. Geophysical Research Letters, 2011.

Cohen, J.B., and R.G. Prinn. Development of a fast, urban chemistry metamodel for inclusion in global models. Atmospheric Chemistry and Physics, 2011]

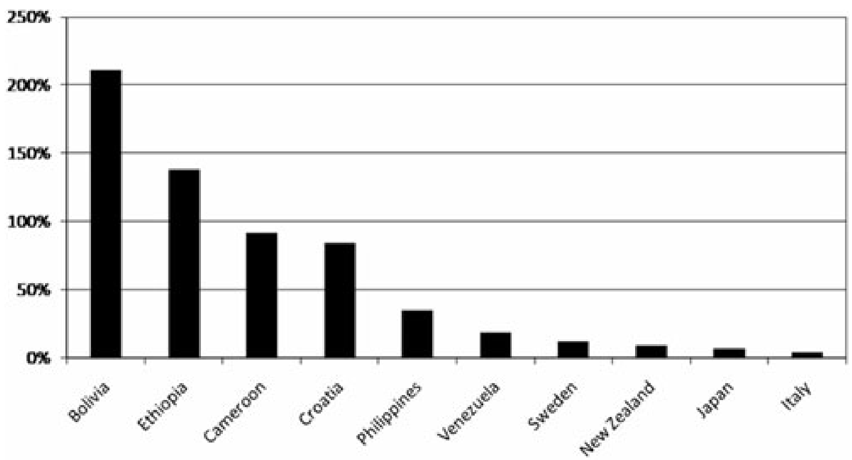
Climate Change: Comparative Impact on Developing and Developed Countries

On the road towards adaptation

No matter how emissions are mitigated in the future, global climate change will require many countries to implement adaptation measures. Not surprisingly, a recent study co-authored by two MIT researchers found that the costs of adaptation are significantly greater in developing countries than in developed countries.

The study notes that the past decade has witnessed a significant rise in the number of "climate events", as well as the number of people affected by such events. Nations are often prepared for what they consider to be inevitable natural disasters, like floods and earthquakes. But climate-based events go beyond these recognized incidences, encompassing systemic changes in the intensity or frequency of extreme weather or long-term changes in climatic norms. And unfortunately, the authors observe, climate change is not limited to governments that have the economic resources to successfully respond to long-term change.

The study sought to measure the disparity between the climate-induced adaptation costs imposed on developed versus developing countries. However, monetary expenditures alone fail to address the relative impact of climate change on a country. The researchers developed a method to measure the ability of a country to absorb predicted costs, including the ability for developing nations to continue along their designed development path without diverting devoted funds to adaptation purposes.



The cumulative opportunity costs as percentage opportunity lost to expand the existing paved road network through 2100 illustrate the relative impact of climate change on lower-income countries versus higher-income countries.

Ten representative countries of similar size but of different economic levels were selected. Then, using global climate models combined with economic and infrastructure data, predicted climate impacts were measured on a single infrastructure element: roads.

Roads are a key element in development, providing access to basic services and means to generate income. The study focused on the effects of precipitation and temperature stresses on paved and unpaved roads to determine the country-specific opportunity cost of climate adaptation (the percent of a country's paved road network that could have been increased/ improved if expenditures were not diverted to adapting to climate change). The costs to countries that implement an adaptation strategy, where roads are maintained using standards continuously updated to consider anticipated climate effects, are compared to costs without an adaptation strategy.

The authors found that opportunity costs to developing countries are significantly greater than for developed countries. In fact, developing countries will be forced to transfer a considerable percentage of their annual expenditures to offset the effects of climate change on road infrastructure.

In Ethiopia for example, initial costs are incurred as existing roads, not designed to withstand climate effects, require maintenance. However, costs decline as adaptation with improved standards occurs, moderating the effects of climate change through 2050. After 2050 though, climate effects overwhelm these measures and a greater percentage of expenditures is required to offset potential damage to roads. Even so, this example demonstrates how an adaptation strategy can significantly decrease the overall costs of climate change, as roads acquire enhanced drainage and improved designs.

In the end, government officials are responsible for making policy decisions with both climate change risks and economic development goals in mind. For adaptation costs, opportunity loss drives the disparity between developed and developing nations. As roads are crucial to development and growth, public officials will need to balance short-term development needs with the potential long-term climate effects on infrastructure.

[Chinowsky, P., Hayles, C., Schweikert, A., Strzepek, N., Strzepek, K., & C. A. Schlosser. Engineering Project Organization Journal, September, 2011]

Reprint 2011-12: Contribution of Anaerobic Digesters to Emissions Mitigation and Electricity Generation Under U.S. Climate Policy

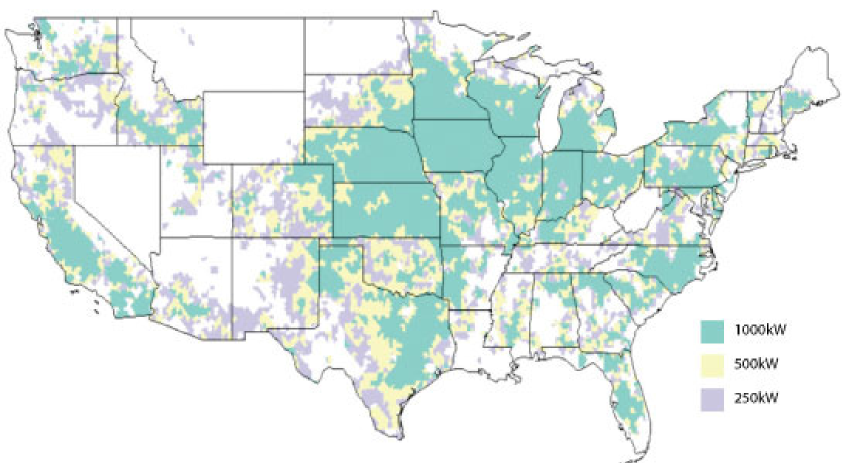
A win-win opportunity for agriculture and energy

Livestock husbandry in the U.S. significantly contributes to many environmental problems, including the release of methane.

When thinking about renewable energy sources, images of wind mills and solar panels often come to mind. Now add to that picture livestock manure. Researchers from the MIT Joint Program on the Science and Policy of Global Change have found that the implementation of climate policies in the US could hasten adoption of anaerobic digesters as a source for renewable electricity.

Anaerobic digesters break down organic wastes using methane-producing bacteria. This methane can then be captured and burned to generate electricity. But anaerobic digesters have several other benefits besides production of renewable energy.

Traditional livestock manure management techniques include storing manure in anaerobic pits or lagoons, which release methane emissions into the atmosphere. In the US, these emissions account for 26% of agricultural emissions of methane, a potent greenhouse gas. Diverting these emissions towards electricity generation thus reduces total US greenhouse gas emissions and may qualify for low-carbon energy subsidies and methane reduction credits. Anaerobic digesters can also reduce odor and pathogens commonly found in manure storage and digested manure can be applied to crops as a fertilizer.



Readily available manure resources can contribute over 11 000 MW of electricity generation potential. Each colored grid cell can support an anaerobic digester of a given capacity.

In collaboration with the University of Wisconsin, researchers used the MIT Emissions Prediction and Policy Analysis (EPPA) model to test the effects of a representative US climate policy on the adoption of anaerobic digesters. Currently, support for anaerobic digesters has been limited in the US and the economic value of most systems is insufficient to promote widespread adoption.

The lack of widespread use of anaerobic digesters is not due to lack in availability; the researchers estimate that cattle, swine, and poultry manure deposited in lagoons or pits currently has the potential to produce 11,000 megawatts of electricity (for scale, one megawatt can power 1000 homes for one instant). The main reason for the lack of anaerobic digesters is that they compete with electricity from cheaper, traditional sources. However, under a climate policy that puts a price on all emissions, electricity produced from fossil fuels become more expensive, and low-carbon energy sources become more competitive.

The study found that, under a representative climate policy, anaerobic digesters are introduced in 2025 when the price of CO_2- equivalent (CO_2e) is $76/tonne. By 2050, use of anaerobic digesters would contribute 5.5% of national electricity generation and would mitigate 151 million metric tons of CO_2e, mostly from methane abatement. These mitigated emissions would also allow the livestock operations to sell emissions permits, adding economic value to the process.

Overall, the researchers identified a win-win situation, where incentives to reduce greenhouse gases would result in both market benefits (cheaper energy generation and sale of emissions credits) and non-market co-benefits (environmental and health gains, fertilizer uses) from adoption of anaerobic digester operations. Such incentives, in the form of climate policies that provide methane reduction credits and increase the costs of electricity from fossil fuels, provide the opportunity for a novel linkage between agriculture and energy production.

[Zaks, D.P.M., N. Winchester, C.J. Kucharik, C.C. Barford, S. Paltsev and J.M. Reilly. Environmental Science and Technology, 45(16): July 2011]

Why are hurricane forecasts still so rough?

Thursday, August 25, 2011, CNN

by Kerry Emanuel, Special to CNN

At this moment, Hurricane Irene poses a risk to almost everyone living along the Eastern Seaboard, from Florida to the Canadian Maritimes. Where will Irene track? Which communities will be affected and how badly? Millions of lives and billions of dollars are at stake in decisions made by forecasters, emergency managers and all of us who live in or own property in harm's way.

It is natural to wonder how good the forecasts are likely to be. To what extent can we trust the National Hurricane Center, local professional forecasters and emergency managers to tell us what will happen and what to do? Undeniably, enormous progress has been made in the skill with which hurricanes and other weather phenomena are predicted. Satellites and reconnaissance aircraft monitor every hurricane that threatens the U.S., collecting invaluable data that are fed into computer models whose capacity to simulate weather is one of the great wonders of modern science and technology.

And the human effort and taxpayer funds that have been invested in this endeavor have paid off handsomely: A three-day hurricane track forecast today is as skillful as a one-day forecast was just 30 years ago. This gives everyone more time to respond to the multiple threats that hurricanes pose.

And yet there are still things we don't know.

For example, we do not know for sure whether Irene will make landfall in the Carolinas, on Long Island, or in New England, or stay far enough offshore to deliver little more than a windy, rainy day to East Coast residents. Nor do we have better than a passing ability to forecast how strong Irene will get. In spite of decades of research and greatly improved observations and computer models, our skill in forecasting hurricane strength is little better than it was decades ago. Why is this so, and how should we go about making decisions in the context of uncertain forecasts?

Since the pioneering work of Edward N. Lorenz in the early 1960s, we have known that weather, including hurricanes, is an example of a chaotic process. Small fluctuations (Lorenz's "butterfly effect") that cannot be detected can quickly amplify and completely change the outcome in just a few days. Lorenz's key insight was that even in principle, one cannot forecast the evolution of some kinds of chaotic systems beyond some time horizon.

In the case of weather, meteorologists think that time horizon is around two weeks or so. Add to this fundamental limitation that we measure the atmosphere imperfectly, sparsely and not often enough, and that our computer models are imperfect, and you arrive at the circumstance that everyone knows from experience: weather forecasts are not completely reliable, and their reliability deteriorates rapidly the further out in time the forecast is made. A forecast for a week from today is dicey at best, and no one even tries to forecast two weeks out. But in the past decade or two, meteorologists have made another important advance of which few outside our profession are aware: We have learned to quantify just how uncertain any given forecast is.

NASA / NOAA GOES-13 satellite image showing Hurricane Irene on August 26, 12:32 UTC.

This is significant, because the degree of uncertainty itself varies greatly from one day to the next. On one occasion, we might be able to forecast a blizzard five days out with great confidence; on another, we might have very little faith in tomorrow's forecast.

We estimate the level of confidence in a particular forecast by running many different computer models many times, not just once. Each time we run it, we feed it a slightly different but equally plausible estimate of the current state of the atmosphere, given that our observations are few, far between and imperfect. In each case, we get a different answer; the differences are typically small to begin with but can grow rapidly so that by a week or so, the difference between any two forecasts is as great as the difference between any two arbitrary states of the weather at that time of year. No point in going any further!

But we observe that sometimes and in some places, the differences grow slowly, while at other times and places, they may grow much more rapidly. And by using different computer models, we can take into account our imperfect understanding of the physics of the atmosphere. By these means, we can state with some accuracy how confident we are in any particular forecast for any particular time and place. Today, one of the greatest challenges faced by weather forecasters is how best to convey their estimates of forecast confidence to the public.

Ideally, we would like to be able to say with full scientific backing something like "the odds of hurricane force winds in New York City sometime between Friday and Sunday are 20%." We have far to go to perfect these, but probabilistic statements like this are the best for which we can hope.

We know from experience that everyone will deal with such probabilistic forecasts in their own way: People have a very broad range of risk aversion. But the next time you are inclined to criticize weather forecasters for assigning probabilities to their forecasts, remember this essay and consider how much better off you are than with other types of forecasters you rely on. Your stockbroker, for example.

Kerry Emanuel is a Professor of Atmospheric Science and director of the Program in Atmospheres, Oceans, and Climate at MIT. The opinions expressed in this commentary are solely those of Kerry Emanuel.

Claudia Octaviano models electricity and oil sectors in Mexico

Though trained as an environmental economist, Claudia Octaviano is currently working towards her PhD in the Engineering Systems Division at MIT. But an economist among engineers isn't as odd as it sounds; Claudia's program integrates engineering, social sciences, and policy to address environmental issues.

"The idea within the Engineering Systems Divisions is that these are very complex issues that you won't be able to solve just by looking at technology, or with just the economics," she explains. "You need to integrate the three parts. They call it Complex Systems Analysis."

Originally from Mexico, Claudia studied the costs to society from power plant pollution, moving on to air quality and evaluation techniques at Yale, and finally focusing on climate change. Her work with Mario Molina and the Mexican Minister of Energy, on developing energy pathways that could lead Mexico towards long-term economic development, led her to MIT in 2009.

Claudia's work in the Joint Program centers on determining Mexico's mitigation potential through the use of sectoral approaches. By implementing policies to decarbonize the electricity sector, for example, Mexico could trade emissions with other countries that have either economy-wide or sectoral cap-and-trade systems. Because the electricity sector contributes a big share of emissions, a sectoral cap could result in a significant environmental benefit. However, focusing only in one sector of the economy means higher costs and efficiency loss when compared to an economy-wide cap-and-trade system.

Still, Claudia's opinion on the matter is: "Do you want an everything-or-nothing situation, or do we start with something? The International Energy Agency proposes that large developing countries can start [mitigation measures] through sectoral trading. It could be a first approach to an [economy-wide] cap-and-trade system."

Claudia works to improve the Joint Program's Emissions Prediction and Policy Analysis (EPPA) model to more accurately reflect the electricity and oil sectors in Mexico. Her research will reveal which technologies will become important in Mexico under different future climate policy scenarios. These findings will also determine the costs of alternative mitigation options.

Political will does not seem to be a barrier to addressing climate change in Mexico, Claudia explains. In fact, she believes the Mexican administration is very willing to address climate change but lacks funds. Yet beyond the issue of money, she also feels that capacity building and technology transfers from developed countries are crucial. "We can do a lot if we learn to prioritize and if we accelerate the state-of-the-art technologies available."

Looking forward, Claudia draws inspiration from Dr. Mario Molina. "He is very influential. People don't always want to hear only economic equations— they want to hear a story. We need someone like Dr. Molina to tell a story. I have my model… now how do I tell a story about it?"

Stephanie Dutkiewicz follows the motion of the ocean, its nutrients, and phytoplankton

A research scientist in MIT's Earth, Atmospheric, and Planetary Science department, Stephanie Dutkiewicz focuses on biogeochemical cycling and phytoplankton distribution in the ocean. Her research follows the circulation of the ocean, from the surface waters to the depths, and back. Within that cycle, Stephanie focuses on another cycle: she models how oceanic circulation affects the flux of carbon and other nutrients, how the consequent availability of these nutrients drives phytoplankton distributions, and how changes in the phytoplankton community in turn drive changes in nutrient distribution.

Stephanie's work begins with 3-Dimensional modeling of how ocean waters move and mix, an effort accomplished through collaboration with MIT research scientist Jeffrey Scott. She then overlays information on how carbon, nitrogen, phosphorus, and other nutrients move on top of these computer simulations.

Next, Stephanie models the biological component. "The oceans are responsible for about 50% of primary production," explains Stephanie. "So 50% of the sunlight that is taken into the body of plant-like organisms (phytoplankton) occurs in the ocean." These organisms take up carbon and other nutrients and, upon dying, some fraction sink to the bottom of the ocean, carrying those nutrients with them.

But not all phytoplankton are created equal— some species are better able to act as carbon sinks than others. Phytoplankton structure and type is driven by ocean circulation and the distribution of nutrients. Large species pull more carbon into deep ocean reservoirs when they sink; smaller species less.

As climate change affects ocean circulation and nutrient availability, some species may become "winners", filling ecological niches and spreading to new geographical regions. Other species may die out. Stephanie models how these community structures change in the future, and how those changes in turn affect carbon cycling.

Unfortunately, it seems climate change favors mostly the smaller species, resulting in less of a carbon sink. "Understanding climate change means understanding feedbacks," says Stephanie. "If the ocean takes up less carbon, that's a feedback into the carbon system."

During her 12 years at MIT, Stephanie has contributed to the development of the Joint Program's Integrated Global Systems Model (IGSM) and collaborated with the MIT Climate Modeling Initiative and the Darwin Project. "I really like the group of people I'm working with. Developing this model has been quite exciting— it's a good place to be."

Students, young and old, gathered on September 20th to watch Dr. Susan Solomon present the Houghton Lecture : “Thoughts on Some Factors That Led Up to the Signing of the Montreal Protocol to Protect the Ozone Layer”

MIT Joint Program Sponsors

The work of the Joint Program is funded by an international partnership of government, industry, and foundation sponsors, and by private donations. Our sponsor consortium provides the long-term substantial commitment needed to support our dedicated and specialized staff, and to realize a coordinated integrated research effort.

Alstom Power (USA)
American Electric Power (USA)
AREVA (France)
Bank of America Merrill Lynch (USA)
BP (UK)
Cargill (USA)
Centro Mario Molina (Mexico)
Chevron (USA)
Chinastone Energy Fund (China)
CONCAWE & EUROPIA (EU)
ConocoPhillips (USA)
Constellation Energy Group (USA)
Deutsche Bank (USA/Germany)
DONG Energy (Denmark)
Duke Energy (USA)
Electric Power Research Institute (USA)
Electricité de France (France)
Eni (Italy)
Exelon (USA)
Exxon Mobil (USA)
GDF SUEZ (France/Belgium)
J-Power (Japan)
Lockheed Martin (USA)
Marathon Oil (USA)
Murphy Oil (USA)
Norwegian Ministry of Petroleum and Energy (Norway)
Repsol (Spain)
Rio Tinto (UK/Australia)
RWE Power (Germany)
Shell International Petroleum (Netherlands/UK)
Southern Company (USA)
Statoil (Norway)
Suncor Energy (Canada)
Tokyo Electric Power Company (Japan)
Total (France)
Toyota Motor North America (USA)
Vattenfall (Sweden)
Vetlesen Foundation (USA)

U.S. Department of Agriculture [USDA]
U.S. Department of Energy [DOE]
U.S. Department of Transportation [DOT]
U.S. Environmental Protection Agency [EPA]
U.S. Federal Aviation Administration [FAA]
U.S. National Aeronautics and Space Administration [NASA]
U.S. National Renewable Energy Laboratory [NREL]
U.S. National Science Foundation [NSF]

MIT JOINT PROGRAM ON THE

Science & Policy of Global Change

Global Changes is published tri-annually by the MIT Joint Program on the Science and Policy of Global Change, explicitly for our program sponsor membership. It reports on research results and news/events around the Joint Program.
All articles and reports are written by Allison Crimmins unless otherwise noted.

Copyright © 2011
MIT Joint Program on the
Science and Policy of Global Change
77 Massachusetts Avenue, E19-411
Cambridge, MA 02139 USA

E-mail: globalchange@mit.edu
Phone: (+1) 617.253.7492
Fax: (+1) 617.253.9845

For inquiries, permission to reproduce material, or to subscribe to future newsletters, please email: globalchange@mit.edu