GLOBAL CHANGES

MIT JOINT PROGRAM ON THE SCIENCE & POLICY OF GLOBAL CHANGE

SPRING 2019 NEWSLETTER

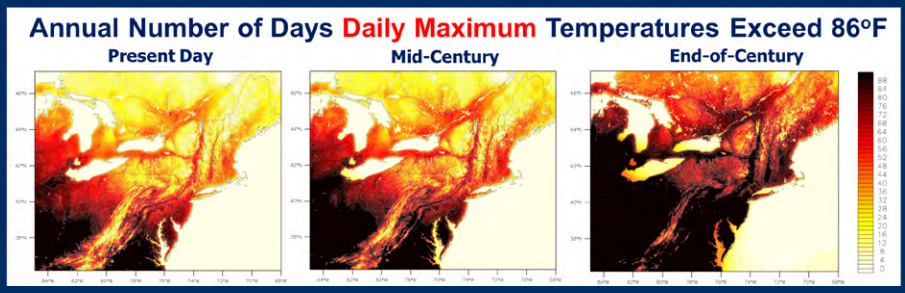
OUR RESEARCH MISSION

At the Joint Program, our integrated team of natural and social scientists studies the interactions among human and Earth systems to provide a sound foundation of scientific knowledge. Such a foundation will aid decision-makers in confronting the interwoven challenges of future food, energy, water, climate and air pollution issues, among others.

Our mission is accomplished through:

- *Quantitative analyses of global changes and their social and environmental implications, achieved by employing and constantly improving an Integrated Global System Modeling (IGSM) framework;*
- *Independent assessments of potential responses to global risks through mitigation and adaptation measures;*
- *Outreach efforts to analysis groups, policymaking communities, and the public; and*
- *Cultivating a new generation of researchers with the skills to tackle complex global challenges in the future.*

In This Issue:



A new study projects that compared to today's climate, the annual number of days in which maximum and mean temperatures exceed 86 degrees Fahrenheit in the U.S. Northeast will increase toward the middle of the century, and even more so toward the end of the century (see page 5).

MIT JOINT PROGRAM ON THE SCIENCE AND POLICY OF GLOBAL CHANGE

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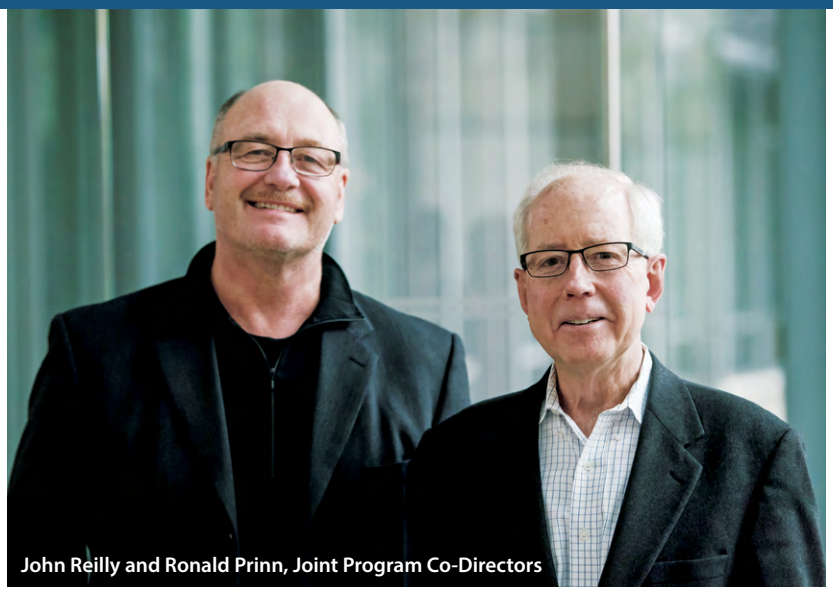
Growing demands on natural resources underscore need for risk assessment and response


John Reilly and Ronald Prinn, Joint Program Co-Directors

The world's natural resource base—water, arable land, minerals and energy—also underpins its economic prosperity. It's possible to have a prosperous economy with few of these resources—think Hong Kong or Singapore—as well as the exact opposite situation, as is the case in parts of the African continent. So how a nation uses and manages natural resources is as important as how much of them it possesses. And the success of countries with limited resources often depends on trade. Over the course of this century, as the world's population and economies expand to unprecedented levels, many analysts anticipate multiple, global crises involving natural resources: water shortages, ecosystem disruption from land expansion, and excessive pollution from fossil fuel use. Others are more optimistic that technological change, improved yields, increased energy efficiency and better management of clean water resources will save the day.

The bottom line is that global demands for energy, food and water are expected to heighten risks to these interrelated natural resources—and the economies that depend on them—in the coming decades. Our latest projections for each of these sectors, published in the *2018 Food, Water, Energy and Climate Outlook* and in peer-reviewed journals, indicate a growing need for risk assessment and response. Here we summarize these projections through midcentury, and highlight how our researchers are assessing risk and identifying opportunities to mitigate that risk.

Our energy, agriculture and water projections

In the Outlook we project that, between 2015 and 2050, the population will increase to about 9.8 billion and the world GDP annual growth rate will remain at about 2.6%. These trends in population and GDP increase pressure on natural resources including energy, land and water. As noted above, this pressure is offset in part by technological change that increases yields and reduces energy use per unit of production activity, and other broad-scale efficiency improvements. Also playing a key role in driving global change are energy and land-use policies, and water management, which could significantly modify the effects of population and economic growth.

We estimate that global primary energy use rises to about 730 exajoules (EJ) by 2050, up from about 550 EJ in 2015. And without significant new policies beyond current Paris pledges, the share of fossil energy (coal, oil, gas) only drops from about 84% in 2015 to 78% by 2050. As a result carbon dioxide (CO_2) and other pollutant emissions continue to increase, contributing further to climate change and to gaseous (e.g. ozone) and particulate (e.g. black carbon) air pollution, which, in turn, affect human health and crop productivity.

The agriculture and water sectors will be shaped not only by increasing demands from population and economic growth but also by the changing global environment. Climate change is likely to add to water stress and reduce agricultural productivity in many regions, but adaptation and agricultural development offer opportunities to overcome these challenges.

Incorporating recent econometric evidence on the relationship between population, income and food demand, our projections show that, at the global level between 2015 and 2050, the value of overall food production increases by about 130%, crop production increases by 75% and livestock production by 120%. While final demand for crops grows only about as fast as population growth, a projected shift to more meat consumption creates additional demand for crops for livestock feed.

Our projections suggest that this can be achieved with a relatively modest increase in land devoted to crops and livestock. This depends, however, on continued availability of water for irrigation, continued technological progress that improves crop and livestock productivity and transforms the global food sector, and absence of policies restricting

livestock. One concern here is that continuing conversion of land for livestock production contributes to CO_2 emissions from land-use change, and growing ruminant numbers add to methane emissions.

Our earlier work on the future of global water resources found that by 2050, economic growth and population change alone can lead to an additional 1.8 billion people living under at least moderate water stress, with 80% of these located in developing countries (Schlosser et al., 2014). The combined effects of socioeconomic growth and uncertain climate change lead to a 1.0–1.3 billion increase of the world's 2050 projected population living with overly exploited water conditions, where total potential water requirements will consistently exceed surface water supply.

An essay in the 2018 Outlook by Joint Program Deputy Director C. Adam Schlosser highlights a more imminent risk. "Assuming [current trends in population and economic growth], and no global efforts to adopt more efficient water use, over the next decade the world will no longer have the capacity to sustain every human at modern living standards," the essay adds. "By these measures, this constitutes an unprecedented global threat."

Risk assessment and response

Joint Program researchers are actively assessing changing demands and potential technology advances in the use of energy, agriculture and water resources to point toward possible hot spots where crises may develop, and evaluating options for managing these resources sustainably.

On the energy front, we continue to investigate different technology options and costs, including nuclear, carbon capture and storage (CCS) and renewables. The costs of renewables are falling, but we still need to account for intermittency—the fact that the daily and seasonal patterns of supply from these resources do not closely match the patterns of demand. So while the base cost of a wind turbine or solar photovoltaic system may make them competitive with other generation technologies, the added cost of ancillary services makes high reliance on these sources within an electricity grid more costly.

In agriculture we're looking at how food demand may grow with increased income. More meat-intensive diets will increase water and land demands. Can land-use policy intensify production on available land, and at what cost? How much water will agriculture need, and will limits on water availability increase food costs? Another concern is that expanding agriculture will be a significant contributor to climate change due to greenhouse gas emissions and surface reflectivity (albedo) changes.

Finally, increased risks of water shortages are likely to emerge if we don't change how we use water. But we see many options to reduce water use while maintaining water-using sectors of the economy. The main problem is that water resources are often poorly managed. There is overuse in some sectors and under-recovery of the full cost of investments in water infrastructure, and hence difficulty in maintaining these systems. Work in this area needs to focus not only on physical risk of water shortages, but also on institutional guidelines and mechanisms for managing these resources.

In our 2018 Outlook, the goal was to identify not only the most likely future but also the potential high-risk outcomes. We used our models to demonstrate how advanced technology or different management approaches and policies can potentially limit bad outcomes. In so doing, we hope to have provided greater confidence that proactive, prediction-based risk-reduction measures that have the greatest likelihood of success can be identified. Multi-sectoral modeling efforts are beginning to provide the much needed risk-based prognoses necessary to explore solutions across a range of possible outcomes that take account of how these natural resource issues are not independent, but highly intertwined.

—Ronald Prinn and John Reilly, Co-Directors

REFERENCES

Reilly, J., R. Prinn, H. Chen, A. Sokolov, X. Gao, C.A. Schlosser, J. Morris and S. Paltsev (2018): *Food, Water, Energy and Climate Outlook.* MIT Joint Program on the Science and Policy of Global Change. http://globalchange.mit.edu/Outlook2018

Schlosser, C.A., K. Strzepek, X. Gao, C. Fant, É. Blanc, S. Paltsev, H. Jacoby, J. Reilly and A. Gueneau (2014): The future of global water stress: An integrated assessment. *Earth's Future*, 2(8): 341–361 (doi:10.1002/2014EF000238). https://globalchange.mit.edu/publication/16014

MIT DEPARTMENT ACRONYMS

Due to space considerations, MIT departments, labs and centers referenced throughout *Global Changes* are referred to by their acronyms.

AGAGE	Advanced Global Atmospheric Gases Experiment
CEE	Civil and Environmental Engineering
CEEPR	Center for Energy and Environmental Policy Research
CGCS	Center for Global Change Science
DUSP	Department of Urban Studies and Planning
EAPS	Earth, Atmospheric and Planetary Sciences
IDSS	Institute for Data, Systems, and Society
MITEI	MIT Energy Initiative

MIT Joint Program News Releases:
Latest research developments and their implications

MIT Joint Program in the Media:
Latest coverage of our research

AROUND CAMPUS *articles feature work by Joint Program affiliates who are not supported by the Program's funding. The following summaries are listed by primary research focus area, but may span multiple research focus areas.*

Food, Water & Forestry

The future of food production amid global change

MIT Joint Program workshop explores risks and opportunities for the agriculture sector

Attendees from industry, government and academia engaged in detailed discussions with Joint Program agriculture specialists, each of whom delivered presentations on three panels focused on driving forces for agriculture, agriculture as contributor to global change, and climate risks for agriculture.

Aerosols threaten water resources in Asia

MIT study underscores growing concern

Airborne particulates, or aerosols, produced by coal-burning power plants and other human activities may help offset global warming, but they may also reduce rainfall in regions that are already water-stressed. An MIT study in *Geophysical Research Letters* found widespread cooling across the Northern Hemisphere and strong suppression of precipitation over East and Southeast Asia.

Workshop explores national security repercussions of climate change

Experts assess potential global destabilization caused by climate change impacts on water supplies, land use, and migration

The Joint Program projects significant water stress in Asia by mid-century, but a combination of climate mitigation and adaptation measures, such as lowering greenhouse gas emissions and irrigating more efficiently, could reduce the severity of the problem, said Program Deputy Director C. Adam Schlosser, one of several experts presenting at a recent MIT Climate Change and National Security Workshop.

AROUND CAMPUS Eruption spurs creation of real-time air pollution network

Low-cost sensors on Hawaii's Kilauea volcano provide an educational resource and give insight into air quality across Big Island

Since installing sensors to measure sulfur dioxide and particulates, MIT CEE researchers have collected a unique dataset on the air quality across the island. They are currently analyzing their measurements from the eruption of Kilauea to better understand the atmospheric transport and transformation of the components of vog, clouds of ash particles and toxic gases from the volcano.

AROUND CAMPUS In China, a link between happiness and air quality

Moods expressed on social media tend to decline when air pollution gets worse, study finds

An MIT DUSP-led paper in the journal *Nature Human Behaviour* reveals that higher levels of pollution are associated with a decrease in people's happiness levels. Research has previously shown that air pollution is damaging to health, cognitive performance, labor productivity and educational outcomes, but air pollution also has a broader impact on people's social lives and behavior.

Throughout the MIT Joint Program's agriculture workshop, attendees from industry, government, and academia engaged in detailed discussions with Joint Program agriculture specialists.

Regional Analysis

Addressing Africa's sustainable development

Researchers and experts attend African Sustainable Development Conference at MIT

Climate change, a surging population and increasing demand for food, housing and natural resources present Africa and the world with extraordinary challenges. In September, numerous experts from diverse disciplines and areas of the world convened at MIT to discuss sustainable development in Africa.

China's giant transmission grid could be the key to cutting climate emissions (*Technology Review*)

But are the country's next-generation power lines a clean-power play or a global power move?

A more flexible, responsive grid is needed to boost renewable electricity in China, says MIT Sloan School of Management Assistant Professor Valerie Karplus.

Air Quality & Health

Mercury pollution is way up. One huge culprit? Gold mines (*Wired*)

The damages go far beyond those inflicted on miners

MIT IDSS/EAPS Associate Professor Noelle Selin highlights how mercury pollution circulates in the environment and poses health risks.

EPA head says rollbacks will keep environment clean, economy up (*WITF*)

Points to report showing U.S. greenhouse gas emissions fell by 3 percent in 2017

MIT Joint Program Co-Director John Reilly explains why U.S. power sector emissions declined in 2017 despite regulation rollbacks.

Study: Impact of mercury-controlling policies shrinks with every five-year delay

Toxin will accumulate in the environment, particularly in remote regions, as countries delay implementing emissions controls

A paper in the journal *Environmental Science and Technology* shows that, for every five years that countries delay in cutting mercury emissions, the impact of any policy measures will be reduced by 14 percent on average. "We will be dealing with mercury for a long time, but we could be dealing with a lot more of it the longer we delay controls," says study author and MIT IDSS/EAPS Associate Professor Noelle Selin.

Once mercury is emitted, the gas can drift through the atmosphere for up to a year before settling into lakes and oceans.

Natural Ecosystems

Study: Much of the surface ocean will shift in color by end of 21st century

Climate-driven changes in phytoplankton communities will intensify the blue and green regions of the world's oceans

Climate change is causing significant changes to phytoplankton in the world's oceans, and an MIT study in the journal *Nature Communications* finds that over the coming decades these changes will affect the ocean's color, intensifying its blue regions and its green ones. Satellites should detect these changes in hue, providing early warning of wide-scale changes to marine ecosystems.

Climate change will even change the color of the oceans, study says (*CNN*)

Blue and green hues to intensify

Changes in phytoplankton populations are expected to impact the food web and carbon cycle, says Principal Research Scientist Stephanie Dutkiewicz. (Additional coverage: *The Washington Post, The Guardian, National Geographic, BBC News, WBUR, Fox News Channel, USA Today, The HIll, UPI, Newsweek, Forbes, Fast Company, Popular Mechanics, Smithsonian, Discover, The Telegraph, The Independent, The Week, The Weather Channel*)

A new MIT study finds that over the coming decades, climate change will affect the ocean's color, intensifying its blue regions and its green ones.

Energy

Charting the Earth's future for the 21st century

MIT report highlights challenges and opportunities for conserving natural resources and stabilizing the climate

Based on a rigorous, integrated analysis of population and economic growth, technological change, Paris Agreement NDCs, and other factors, the MIT Joint Program's *2018 Food, Water, Energy and Climate Outlook* projects likely global and regional environmental changes over the course of this century and identifies steps needed to align near-term Paris pledges with the long-term 2°C and 1.5°C goals.

Solar, renewables, energy transformation reshaping the geopolitical landscape (*Solar Magazine*)

The geopolitical calculus is shifting amid rapid growth of decentralized, emissions-free, renewable energy resources

Three leading energy experts, including Joint Program Deputy Director Sergey Paltsev, share their perspectives.

AROUND CAMPUS | COMMENTARY **Why we can't reverse climate change with 'negative emissions' technologies (*The Conversation*)**

NETs must be shown to work on a gigaton scale, at an affordable cost, and without serious environmental impacts. That has not happened yet.

Treating NETs as a way to compensate for breaking the carbon budget and overshooting stabilization targets is more hope than reality, says carbon capture and storage (CCS) expert and MITEI Senior Research Engineer Howard Herzog.

AROUND CAMPUS **Carbon capture is messy and fraught—but it might be essential (*Wired*)**

The challenge is to make carbon capture and storage economically viable

MIT CEEPR Director Christopher Knittel comments on one possible solution: a carbon tax.

Earth System Science

New threat to ozone recovery

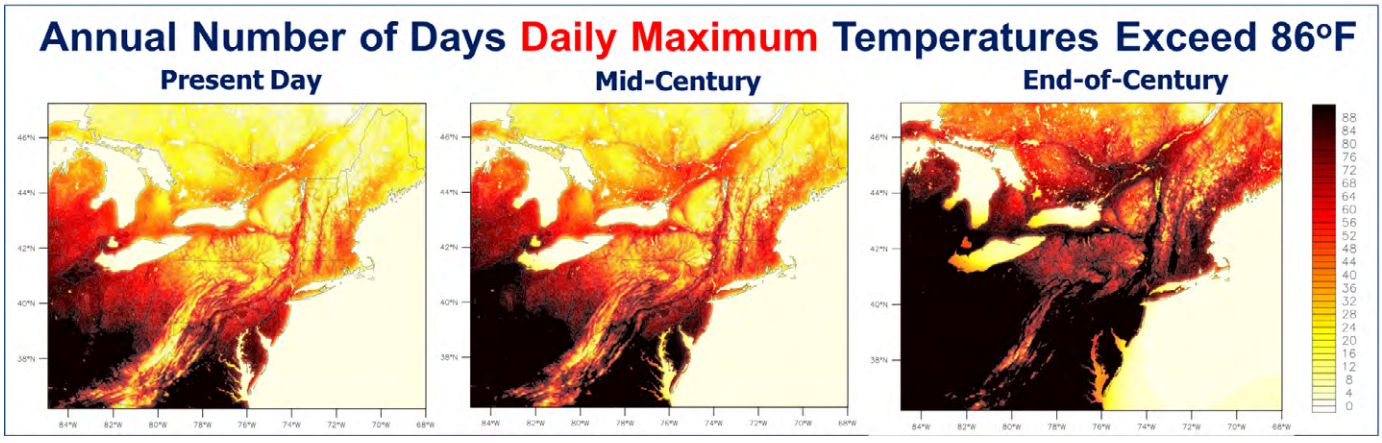
Study finds chloroform emissions, on the rise in East Asia, could delay ozone recovery by up to eight years

An MIT study in the journal *Nature Geoscience* found that between 2010 and 2015, emissions and concentrations of chloroform in the global atmosphere have increased significantly. The researchers traced the source of these emissions to East Asia, where it appears that production of products from chloroform is on the rise. If chloroform emissions continue to increase, the researchers predict that the recovery of the ozone layer could be delayed by four to eight years.

Modeling climate risk where it hits home

Study projects dramatic increase in annual high-heat days in the U.S. Northeast by century's end

Long-term assessment of likely regional and local climate impacts is critical to enabling municipalities, businesses and regional economies to prepare for potentially damaging and costly effects of climate change. To that end, an MIT-led study in the journal *Earth and Space Science* introduces a modeling approach that allows for analysis of changes in more than 200 climate variables within a single 24-hour period.



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EARTH SYSTEM SCIENCE - CONT'D

Monitoring the atmosphere, changing the world

AGAGE network celebrates 40 years of measuring ozone-depleting and climate-warming gases

The Advanced Global Atmospheric Gases Experiment (AGAGE) has measured the greenhouse and ozone-depleting gas composition of the Earth's atmosphere continuously for the past 40 years through a global network of sophisticated monitoring stations. Nearly 40 AGAGE scientists, collaborators and invited guests from around the world discussed the network's evolution, impacts and future at a 40th anniversary conference in October.

Rwanda launched the Medusa Instrument for the Rwanda Global Climate Observatory

Joint Program Co-Director Ronald Prinn and former PhD student Jimmy Gasore recognized for initiating the project

In January the Rwanda Minister of Education officiated a ceremony to launch the first African Air Quality and Climate Laboratory equipped with the "Medusa system" that will measure more than 50 gases that lessen the ozone layer. The equipment will observe climate change in Africa, sense the sources and the amount of the gases being emitted in the region, and inform climate mitigation and adaptation policy.

The world's oceans flunk the #10YearChallenge (*The Daily Beast*)

How hard did aging hit the oceans?

John Reilly comments on impact of rising global temperatures.

AROUND CAMPUS U.S. greenhouse gas emissions spiked in 2018 — and it couldn't happen at a worse time (*Washington Post*)

Global emissions also reached a record high

The U.S. emissions increase dovetails with rising emissions in other countries, including China and India, says MIT CEEPR Deputy Director Michael Mehling.

Climate reality check: Global carbon pollution up in 2018 (*Associated Press*)

Atmosphere undergoes largest increase in carbon dioxide emissions in seven years

Fossil fuels still account for 81 percent of the world's energy, notes John Reilly.

AROUND CAMPUS Climate change makes summer weather stormier yet more stagnant

Study finds rising temperatures feed more energy to thunderstorms, less to general circulation

Climate change is shifting the energy in the atmosphere that fuels summertime weather, which may lead to stronger thunderstorms and more stagnant conditions for mid-latitude regions of the Northern Hemisphere, including North America, Europe, and Asia, a new MIT study finds. These conditions could result in degraded urban air quality and longer-lasting heat waves.

AROUND CAMPUS 3Q: Machine learning and climate modeling

As machine learning expands into climate modeling, EAPS Associate Professor Paul O'Gorman answers what that looks like and why it's important now

MIT EAPS Associate Professor Paul O'Gorman discusses where machine learning fits into climate modeling, possible pitfalls and their remedies, and areas in which the approach is likely to be most successful.

AROUND CAMPUS Arctic ice sets speed limit for major ocean current

Long-term melting may lead to release of huge volumes of cold, fresh water into the North Atlantic, impacting global climate

MIT scientists have identified a key mechanism, which they call the "ice-ocean governor," that controls how fast the Beaufort Gyre—a 600-mile-wide pool of swirling cold, fresh water in the Arctic Ocean—spins and how much fresh water it stores. A paper in *Geophysical Research Letters* reports that the Arctic's ice cover essentially sets a speed limit on the gyre's spin.

Climate Policy

Technology and policy pathways to Paris emissions goals

Two new MIT reports advance practical emissions-reduction strategies for Southeast Asia and Latin America at both the regional and country level

Two Joint-Program/MITEI reports show how well countries in Southeast Asia and Latin America are doing in reducing greenhouse gas emissions, and what steps they can take to move closer to meeting their Paris Agreement pledges. Lead author Sergey Paltsev presented findings from these reports at the 24th Conference of the Parties (COP24) to the UN Framework Convention on Climate Change.

CLIMATE POLICY - CONT'D

PODCAST: Exploring technology and policy options to advance the Paris Agreement

Joint Program Deputy Director Sergey Paltsev and CEEPR Deputy Director Michael Mehling interviewed in MIT Energy Initiative podcasts during COP24 in Katowice, Poland

Three podcasts explore climate policy paths for Asian and Latin American nations, emissions trading and Paris Agreement Article 6, and British Columbia and the energy trilemma. MITEI Communications Director Emily Dahl produced two of the podcasts during the COP24 meeting.

"Climate change will not wait for us"

At UN Climate Change Conference, MIT researchers share knowledge and tools to help nations meet Paris Agreement targets

For two weeks in December, climate negotiations at COP24 focused on rulemaking around implementation of the 2015 Paris Agreement to reduce global greenhouse gas emissions. MIT participants attended the conference to help unleash the power of the Paris Agreement by sharing analyses and insights that can aid nations in determining the right policy and technology solutions for meeting emissions reduction targets.

Study evaluates China's progress in establishing accounting measures to reinforce its Paris pledge

Firms learn from experience in the measurement, reporting and verification of CO_2 emissions under China's emissions trading systems

Building reliable firm-based systems for emissions measurement, reporting and verification (MRV) is no easy task, especially in developing countries where misreporting of environmental data can be significant. An MIT-led study in *Nature Climate Change* focused on China identifies challenges and opportunities to achieve that goal.

Why carbon pricing is more economical than regulations in reducing greenhouse gas emissions

MIT Joint Program deputy director makes the case at first International Research Conference on Carbon Pricing

At the world's first International Research Conference on Carbon Pricing on February 14–15 in New Delhi, India, MIT Joint Program Deputy Director Sergey Paltsev noted that the Program's research has repeatedly shown that emissions trading saves billions of dollars and generates substantial revenues compared to measures aimed at regulating emissions.

COMMENTARY **Managing uncertainty while developing long-term strategies for GHG emission mitigation (*World Resources Institute*)**

An expert perspective

Sergey Paltsev explores key elements of successful long-term climate mitigation strategies.

COMMENTARY **Anchoring long-term strategy in near-term action (*World Resources Institute*)**

An Expert Perspective

That's what's needed in order for the Paris Agreement to succeed, argues Joint Program Founding Co-Director Henry D. Jacoby.

COMMENTARY **Why the next two years are critical for the Paris climate deal's survival (*The Conversation*)**

Meeting the Paris 2°C goal requires a dramatic turnaround in emissions in the very near future

More ambitious climate action must start sooner rather than later to avoid the worst consequences of climate change, argue Joint Program researchers Henry Jacoby and Jennifer Morris.

AROUND CAMPUS **Doomsday Clock stalls at two minutes to midnight—but global threats increase (*Nature*)**

Heightened tensions between nuclear powers and inaction on climate change are the "new abnormal," says the Bulletin of the Atomic Scientists

MIT atmospheric chemist/EAPS Professor Susan Solomon delivers the portion of the *Bulletin* statement focused on climate change, an area of particular concern.

VIDEO **COP24 climate talks (*France 24*)**

Meeting expected to go through weekend

Joint Program Research Scientist Jennifer Morris analyzes extension of the talks in Katowice, Poland.

COMMENTARY **This is what the Green New Deal needs to actually work (*Fortune*)**

Is the Green New Deal (GND) a liberal pipe dream, or is it an opening for an economically viable, bipartisan climate change solution?

John Reilly recommends three guiding principles for a viable GND.

VIDEO **John Reilly discusses the Green New Deal proposal (*China Global Television Network*)**

MIT Joint Program Co-Director explores policy goals, challenges and opportunities

Reilly interviewed by CGTN's Rachelle Akuffo.

It's expensive to (not) mitigate climate change (*The Atlantic*)

The economist John Reilly explains how a carbon tax in America would play out

Reilly and policy experts respond to a natural-gas worker's worries that the fight against climate change will hurt Americans like him.

Trump's wrong. We can still stop apocalyptic global warming (*Daily Beast*)

'Their interpretation of their results is totally backwards,' one scientist said

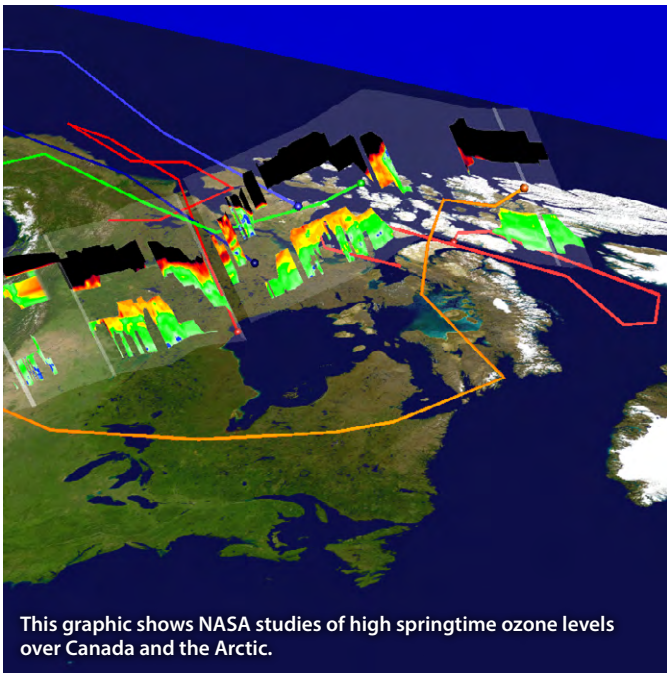
Climate mitigation cannot be effective unless the world acts together, says John Reilly.

Modeling Tools

Projecting global and regional change, enabling informed decision-making

MIT Joint Program researchers to present advanced modeling approaches at AGU Fall Meeting

Seventeen researchers and affiliates of the Joint Program delivered or contributed to 10 oral and poster presentations at the American Geophysical Union (AGU) 2018 Fall Meeting in December in Washington, D.C. Presentations showcased advanced modeling methods for projecting global and regional change—and, in some cases, results that could inform decision-making.



This graphic shows NASA studies of high springtime ozone levels over Canada and the Arctic.

Simple yet effective

Faster, cheaper modeling method could improve understanding of long-term atmospheric chemistry and provide a powerful risk assessment tool

In a study in the European Geosciences Union journal *Geoscientific Model Development,* a team of Joint Program-led researchers has devised a strategy to incorporate simplified chemical mechanisms in atmospheric simulations that can match results produced by more complex mechanisms for most regions and time periods. If implemented in a 3D Earth-system model, the new modeling strategy could enable scientists and decision-makers to perform low-cost, rapid atmospheric chemistry simulations that cover long time periods under a wide range of scenarios.

New Research Projects

Assessment of the Availability, Abundance and Intermittency of Wind Power: Phase 1 – Triage Analyses to Survey Risks of Changes in Wind-Power Availability and Variability

Sponsor: Iberdrola (via the MIT Energy Initiative)
Project Leader: C. Adam Schlosser
Duration: One year

The first phase of this project will employ a hybrid approach that the Joint Program has enabled within the MIT's Integrated Global System Model (IGSM) framework to undertake a "triage risk assessment" of wind and solar power associated with human-forced climate change. By applying this approach to assessing risks in wind power generation, the project leader will perform the following analytical tasks: quantify the associated human-forced trends of wind-power availability and variability; construct a risk-based assessment of wind-power trends by combining the IGSM probabilistic projections with the emerging patterns of change from CMIP models; begin feasibility assessment of this method for solar power diagnoses; and evaluate climate-model wind and solar power estimates. From these proposed research tasks, this Phase 1 effort can provide a "triage assessment" of the likelihood of changes in wind power as a result of human-forced potential climate change. The analyses will draw attention to patterns across the United States, Europe, Central America and Brazil and note particular areas within these regions of interest that present an elevated risk of significant change. The project leader anticipates that the outcomes for this research would provide the impetus for more targeted studies of variability, extremes and predictability to be undertaken in Phase 2 that would provide a more rigorous scientific method toward long-term mitigation and adaptation solutions.

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(2): See p 6.
(3): See p 4.

Joint Program Reprints

2018-10. Description and Evaluation of the MIT Earth System Model (*J Adv Model Earth Sys*)

2018-11. The greening of Northwest Indian subcontinent and reduction of dust abundance resulting from Indian summer monsoon revival (*Scientific Reports*)

2018-12. On the representation of aerosol activation and its influence on model-derived estimates of the aerosol indirect effect (*Atmos Chem Phys*)

2018-13. The Impact of Climate Change Policy on the Risk of Water Stress in Southern and Eastern Asia (*Environ Res Lett*)

2018-14. The Equilibrium Climate Response to Sulfur Dioxide and Carbonaceous Aerosol Emissions from East and Southeast Asia (*Geophys Res Lett*)

2018-15. Effective radiative forcing in the aerosol–climate model CAM5.3-MARC-ARG (*Atmos Chem Phys*)

2018-16. History of chemically and radiatively important atmospheric gases from the Advanced Global Atmospheric Gases Experiment (*Earth Sys Sci Data*)

2018-17. Turkish Energy Sector Development and the Paris Agreement Goals: A CGE Model Assessment (*Energy Policy*)

2018-18. Evaluating Simplified Chemical Mechanisms within CESM CAM-chem: MOZART-4 vs. Reduced Hydrocarbon vs. Superfast Chemistry (*Geosci Model Dev*)

2018-19. Capturing Natural Resource Heterogeneity in Top-Down Energy-Economic Equilibrium Models (*Energy Econ*)

Peer-Reviewed Studies & Pending Reprints

A Critical Time for Mercury Science to Inform Global Policy (*Environ Sci Technol*)

Advanced Technologies in Energy-Economy Models for Climate Change Assessment (*Energy Econ*)

Changes in emissions of ozone-depleting substances from China due to implementation of the Montreal Protocol (*Environ Sci Technol*)

Continued emissions of the ozone-depleting substance carbon tetrachloride from Eastern Asia (*Geophys Res Lett*)

Estimates of Climate System Properties Incorporating Recent Climate Change (*Adv Stat Climatol Meteorol Oceanogr*)

Evaluating EDGARv4.tox2 speciated mercury emissions ex-post scenarios and their impacts on modelled global and regional wet deposition patterns (*Atmos Environ*)

Evaluation of back-trajectory statistical methods and inverse modeling method in locating emission sources (*ACS Earth Space Chem*)

Implications of the Paris Climate Agreement for the Russian economy (*Voprosy Ekonomiki*)

Integrity of Firms' Emissions Reporting in China's Early Carbon Markets (*Nature Climate Change*)

Ocean Colour Signature of Climate Change (*Nature Communications*)

Quantifying coal power plant responses to tighter SO_2 emissions standards in China (*PNAS*)

Recent increases in the atmospheric growth rate and emissions of HFC-23 (CHF_3) and the link to HCFC-22 ($CHClF_2$) production (*Atmos Chem Phys*)

Resilience of the Eastern African electricity sector to climate driven changes in hydropower generation (*Nature Comm*)

Toward resolving the budget discrepancy of ozone-depleting carbon tetrachloride: an analysis of top-down emissions from China (*Atmos Chem Phys*)

Understanding factors influencing the detection of mercury policies in modelled Laurentian Great Lakes wet deposition (*Environ Sci Process Impact*)

Understanding mercury oxidation and air-snow exchange on the East Antarctic Plateau: A modeling study (*Atmos Chem Phys*)

Joint Program Reports

334. Implications of Updating the Input-output Database of a Computable General Equilibrium Model on Emissions Mitigation Policy Analyses

335. Designing Successful Greenhouse Gas Emission Reduction Policies: A Primer for Policymakers – The Perfect or the Good?

TN-17. Emissions inventories and time trends for greenhouse gases and other pollutants

Milestones

For its Best Paper Prize 2018, the *Australian Journal of Agriculture and Resource Economics* awarded an honorable mention to "**The impact of water scarcity on food, bioenergy and deforestation**" by Joint Program co-authors **Niven Winchester**, **Kirby Ledvina**, **Kenneth Strzepek** and **John M. Reilly**.

A paper co-authored by Joint Program Research Scientist **Y-H. Henry Chen**, Co-Director John Reilly and Deputy Director **Sergey Paltsev** and collaborators at the Institute of Nuclear Energy Research (INER), "**Implications of Updating the Input-output Database of a Computable General Equilibrium Model on Emissions Mitigation Policy Analyses**," was accepted for presentation at the **22nd Annual Conference on Global Economic Analysis**. In addition, Chen received the award covering full travel expenses to attend the conference by the GAMS Development Corporation's "Alex Meeraus / Thomas Rutherford Travel Funds" committee.

Sergey Paltsev's paper "**Energy scenarios: the value and limits of scenario analysis**," published in *Wiley Interdisciplinary Reviews: Energy and Environment*, was one of the journal's top 20 most downloaded recent papers.

MIT **CEE** postdoctoral associate **Sarah Fletcher** was selected to receive the American Water Works Association's First Place 2019 **Academic Achievement Award** for the best Doctoral Thesis. The award will be formally presented at AWWA's Annual Conference in June in Denver, Colorado. Fletcher's thesis supervisor was Joint Program Research Scientist Kenneth Strzepek. Her **dissertation** advances a flexible, adaptive approach to water supply infrastructure planning under uncertainty.

Joint Program Communications Coordinator **Jamie Bartholomay** was selected as a 2019 **Infinite Mile Award** winner in the area of the Offices of the Provost and Vice President for Research at MIT. The award recognizes those individuals or teams who have made extraordinary contributions within their own organizations to help the Institute carry out its mission. The winners will be honored at a special award ceremony and reception at MIT in May.

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