GLOBAL CHANGES

MIT JOINT PROGRAM ON THE SCIENCE & POLICY OF GLOBAL CHANGE

FALL 2021 NEWSLETTER

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

OUR RESEARCH MISSION

Advancing a sustainable, prosperous world through scientific analysis of the complex interactions among co-evolving, interconnected global systems.

The pace and complexity of global environmental change is unprecedented. Nations, regions, cities and the public and private sectors are facing increasing pressures to confront critical challenges in future food, water, energy, climate and other areas. Our integrated team of natural and social scientists produces comprehensive global and regional change projections under different environmental, economic and policy scenarios. These projections enable decision-makers in the public and private sectors to better assess impacts, and the associated costs and benefits of potential courses of action.

OUR VISION

We envision a world in which community, government and industry leaders have the insight they need to make environmentally and economically sound choices.

Toward that end, we provide a scientific foundation for strategic investment, policymaking and other decisions that advance sustainable development.

IMPACT: WHAT WE DO

The MIT Joint Program:

- Combines scientific research with risk and policy analyses to project the impacts of—and evaluate possible responses to—the many interwoven challenges of global socioeconomic, technological and environmental change.
- Communicates research findings through our website, publications, workshops and presentations around the world, as well as frequent interactions with decision-makers, media outlets, government and nongovernmental organizations, schools and communities.
- Cultivates and educates the next generation of interdisciplinary researchers with the skills to tackle ongoing and emerging complex global challenges.

IN THIS ISSUE:

SAVE THE DATE: XLIV GLOBAL CHANGE FORUM

Global Net Zero Emissions Goals

Mar 23–24, 2022 • Sponsor Meeting on Mar 22

More information

Attendance is by invitation only.

MIT JOINT PROGRAM ON THE SCIENCE AND POLICY OF GLOBAL CHANGE

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FALL 2021 GLOBAL CHANGES

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Three questions on multi-sector dynamics

How this emerging field can enable decision-makers to minimize risk

Can you define multi-sector dynamics (MSD) and describe what new information it can uncover?

Multi-sector dynamics (MSD) is the study of how multiple, increasingly complex systems—including Earth, environmental, infrastructure, governance and socio-economic systems—change, interact and coevolve. The collective behavior of such systems in response to various stressors and influences can lead to cascading effects and tipping points that pose serious risks to the environment and society.

For example, we all rely on interconnected water, agricultural and energy systems that must be managed in an integrated fashion so that each system is sustainable. Suppose we have a landscape that's intensely cultivated, with a shipping infrastructure that trades and delivers produce to where people need it, and an energy infrastructure that supports both crop cultivation and shipping. If a flood damages infrastructure, destroys crops and disrupts power, you end up with a compounding, collocated event that not only impacts each resource individually but also the supply chain that they serve.

If you assess the risk to just one resource (e.g. crops), you won't begin to understand the full potential impacts and risks associated with that flood. However, if you consider the connections among water, food and energy resources in an integrated MSD study, you have a much greater ability to capture feedbacks and quantify impacts to all three co-evolving resources and the supply chain that depends upon them. MSD analyses can also identify how risks to one system can propagate to other systems, and how seemingly benign events that wouldn't be considered threats individually can compound one another to increase overall risk.

How can MSD modeling empower decision-makers to make more informed policy and investment choices?

By improving our understanding of the interactions and interdependencies among human and Earth systems and evaluating risks to co-evolving systems in combination, our MSD studies provide more comprehensive

C. Adam Schlosser

assessments to inform decision-makers. For example, one of our studies combined data on EPA-designated toxic release sites in the United States with data on flood risk. We showed that many of these toxic release sites are located in areas of high flood risk, posing serious threats to local and downstream residents and infrastructure. The resulting map pinpointed hotspots that need fortification.

Such MSD analyses can inform both decision-makers and those impacted by their decisions, particularly when it comes to environmental inequities. By studying demographic attributes and landscapes in tandem, you can see how environmental risks are not equally distributed across all populations. When we combined a U.S. landscape of water quality risks with one of unemployment, poverty and race, we ended up with a map highlighting hotspots of environmental inequities throughout the country.

What is the Joint Program's current and anticipated future capability in this space?

Our Integrated Global System Modeling (IGSM) framework has long provided the ability to explore connections between human and Earth systems. We continue to expand this modeling framework to include more systems and linkages as well as capture more local scales in order to better address MSD research questions.

Our primary new MSD tool, which we call the Socio-Environmental Risk Triage platform, puts data

on multiple systems in the hands of decision-makers as well as those impacted by compounding risks, and helps pinpoint where action is needed. In its current implementation, the platform allows people to study present-day landscapes in the U.S. and assess today's risks. In its next phase of development, we plan to use projections from our IGSM framework to show how current risks to multiple systems will evolve in the future. While the IGSM framework models changes in human and Earth systems and risks posed by those changes, the risk triage platform will enable us to assess those changes and risks efficiently and transparently.

For example, we have recently begun to more systematically examine the links between climate, health, energy and equity and how to design policies to ensure equitable and just climate and health outcomes. To learn more about our risk triage platform and other MSD modeling tools—and how we are applying them to identify potential tipping points and risks in water quality, land use, economics and energy, health, and infrastructure—see our recent news story and webinar on the Joint Program's MSD research capabilities.

—C. Adam Schlosser, Deputy Director

MIT DEPARTMENT ACRONYMS

Due to space considerations, MIT departments, labs and centers referenced here are referred to by their acronyms.

CEEPR	Center for Energy and Environmental Policy Research
EAPS	Earth, Atmospheric and Planetary Sciences
IDSS	Institute for Data, Systems and Society
ILP	Industrial Liason Program
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

The following summaries are listed by primary research focus area, but may span multiple research focus areas. For more information on Joint Program research, please visit our website at globalchange.mit.edu.

Earth Systems

Changes and risks to interconnected land, ocean, atmosphere and biosphere systems

Study: Global cancer risk from burning organic matter comes from unregulated chemicals

The researchers hope scientists and regulators will consider a broader class of compounds in evaluating cancer risk due to PAH exposure

There are more than 100 known types of polycyclic aromatic hydrocarbons emitted daily into the atmosphere. Regulators, however, have historically relied on measurements of a single compound, benzo(a)pyrene, to gauge a community's risk of developing cancer from PAH exposure. Now MIT scientists have found that benzo(a)-pyrene may be a poor indicator of this type of cancer risk.

Whenever organic matter is burned, such as in a wildfire, a power plant, a car's exhaust, or in daily cooking, the combustion releases polycyclic aromatic hydrocarbons (PAHs) — a class of pollutants that is known to cause lung cancer.

The climate is moving to greater and greater extremes — acting now can reduce risks (The Hill)
A commentary by Joint Program Director Ronald Prinn

Our planet's future: UN's latest climate report (NBC/NECN)
Joint Program Deputy Director Sergey Paltsev explains initial findings of the 2021 IPCC Report

Managed Resources

Changes and risks to managed agriculture, water, land and energy systems

Climate-smart agriculture (CSA) is an integrated set of practices that enable farmers to increase their productivity while adapting to, or even mitigating against, climate change.

Reducing emissions on the farm

New report shows how U.S. agriculture can fight climate change (Farm Journal Foundation)

U.S. agriculture contributes about 10% of the total greenhouse gas emissions of the entire national economy, but farmers could greatly reduce those emissions if they were provided with the right government incentives, according to the report, which was co-authored by the MIT Joint Program's John Reilly and Farm Journal Foundation Senior Policy Advisor Dr. Stephanie Mercier.

Report shows how U.S. farmers can fight climate change (AgWired)

Report co-author/ Joint Program Co-Director Emeritus John Reilly explained how agriculture has the greatest stake in climate change, but also the greatest ability to reduce emissions in a variety of ways (Additional coverage: Michigan Farm News • AgWeb • The Cattle Site • The Poultry Site)

Farmers like me want to join fight against climate change. But we need help (CNN)

Commentary cites MIT Joint Program/Farm Journal Foundation report on how agriculture can help address climate change

Infrastructure & Investment

Physical and transition risk; adaptation and resilience to climate change and extreme events

Campus test bed

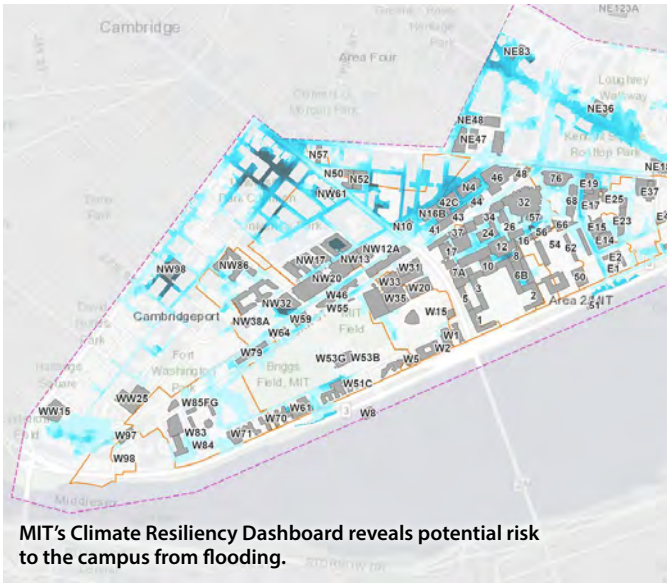
MIT partners with Cambridge on flood-risk model for local, global benefit (MIT Spectrum)

Working with the city and with researchers at the MIT Joint Program, the MIT Department of Facilities, and local engineering consultants, MIT conducted a thorough survey of its drainage systems, mapping every drainpipe, catchment and manhole. With those data, a campus flood-risk model was built that was then integrated into the Cambridge city model.

For campus "porosity hunters," climate resilience is the goal

With the MIT campus as a test bed, a citizen science effort provides lessons well beyond MIT (MIT Office of Sustainability)

The MIT Porosity Hunt is a citizen-science effort that is using the MIT campus as a place to test emerging methodologies, instruments and data collection processes to better understand the potential impact of a changing climate—and specifically storm scenarios resulting from it—on infrastructure. MIT Joint Program Research Scientist Kenneth Strzepek is an integral part of this work.



MIT's Climate Resiliency Dashboard reveals potential risk to the campus from flooding.

INFRASTRUCTURE & INVESTMENT - CONT'D

Climate effects on U.S. infrastructure

The economics of adaptation for rail, roads and coastal development

Changes in temperature, precipitation, sea level and coastal storms will likely increase infrastructure vulnerability across the U.S. Using models that analyze vulnerability, impacts and adaptation, this study estimates impacts to railroads, roads and coastal properties under three infrastructure management response scenarios, concluding that proactive adaptation measures could sharply reduce costs.

MIT Joint Program Deputy Director Sergey Paltsev delivers featured presentation at MATLAB Computational Finance Conference

Talk explores using energy-economic models for climate-related financial impact analysis

Paltsev describes a framework developed at the Joint Program for assessing climate-related financial risks amid a global transition to a low-carbon economy.

For companies to address climate change, an 'action plan' is needed (Yahoo Finance)
Joint Program Deputy Director Sergey Paltsev discusses climate change, the shift to net zero emissions, and how businesses can address climate risks

Paltsev delivers featured presentation at MATLAB Computational Finance Conference
Talk explores using energy-economic models for climate-related financial impact analysis

Energy Transition

National and global projections of the future energy mix; prospects for different sectors and technologies

MIT Joint Program Deputy Director Sergey Paltsev will serve as co-PI on an Imperial College-MIT project tackling climate change *(IAMC)*
Project to advance nature-based solutions for accelerating climate action

Electrification of light-duty vehicles — A partial solution for decarbonization (T&D World)
While electrification of light-duty vehicles can contribute significantly to mitigating greenhouse gas emissions, a more comprehensive approach is needed to complete the job

Are electric cars 'green'? The answer is yes, but it's complicated (CNBC)
Paltsev shares MIT projections for decarbonizing the electric vehicle infrastructure

PODCAST **The battery-powered electric vehicle as a potential climate solution (TBS eFM Radio (Seoul))**
Paltsev explores prospects for decarbonizing EVs

Climate change goals and oil production are clashing in the U.S. (National Geographic)
If we're to avoid extreme warming, all drilling for oil needs to stop now, experts say, but U.S. fossil fuel production is continuing.

Imperial and MIT researchers join forces to tackle pollution and climate change

MIT Joint Program Deputy Director Sergey Paltsev to serve as co-PI on "Nature-based solutions for accelerating climate action" (Imperial College London)

Researchers from Imperial College London and MIT will collaborate to pursue ideas focused on climate solutions and the transition to zero pollution. Seven projects have been funded, including several investigating new approaches to measuring and modelling atmospheric air pollution and one project looking at nature-based solutions to remove carbon dioxide from the atmosphere.

VIDEO: MITEI 2021 Spring Symposium on bioenergy with carbon capture and storage (BECCS)

Six Joint Program researchers and collaborators serve as presenters and moderators

To reach the goal of net-zero greenhouse gas emissions, future energy-use scenarios are increasingly reliant on negative emission technologies such as BECCS. Held in June, this symposium brought together panelists with a variety of expertise on BECCS to explore the contributions it could make in decarbonizing the world's economies and the challenges it faces.

ENERGY TRANSITION - CONT'D

Decarbonizing industry

In the sector where emissions are hardest to cut, carbon capture could be the sharpest knife

Might carbon capture and storage (CCS) alone enable hard-to-abate industries to continue to grow while eliminating nearly all of the CO_2 emissions they generate from the atmosphere? The answer is an unequivocal yes in a new study in the journal *Applied Energy* co-authored by researchers at the MIT Joint Program, MIT Energy Initiative and ExxonMobil.

Electrifying cars and light trucks to meet Paris climate goals

Study gauges the pace of shifting to battery power

How much of the light-duty vehicle (LDV) fleet will need to go electric to keep long-term Paris climate goals in play? To help answer that question, researchers at the MIT Joint Program and MIT Energy Initiative have assessed the potential impacts of global efforts to reduce carbon dioxide emissions on the evolution of LDV fleets over the next three decades.

Researchers at the MIT Joint Program and MIT Energy Initiative have assessed the potential impacts of global efforts to reduce carbon dioxide emissions on the evolution of light-duty vehicle fleets over the next three decades.

Policy Scenarios

Environmental and economic change under different climate, air pollution, and economic policies

Why the Earth needs a course correction now

2021 Global Change Outlook shows how more aggressive policies can sharply reduce climate risk

In May the Joint Program released its *2021 Global Change Outlook*. Based on a rigorous, integrated analysis of population and economic growth, technological change, NDCs, Covid-19 impacts and other factors, the report presents the Program's latest projections for the future of the Earth's energy, food, water and climate systems, and prospects for achieving the Paris Agreement's climate goals.

POLICY SCENARIOS - CONT'D

VIDEO: 2021 Global Change Outlook Webinar

Lead authors of the MIT Joint Program's signature publication present the Outlook's projections of future energy, water, food, climate, and policy prospects

In this 90-minute webinar, Joint Program Director Ronald Prinn delivers introductory remarks and Deputy Directors Sergey Paltsev and Adam Schlosser present an overview of the Outlook and key findings, followed by Q&A.

Smarter regulation of global shipping emissions could improve air quality and health outcomes

Study shows need to identify domestic and international pollution sources in policy design

Effective mitigation of the air quality and health impacts of global shipping emissions will require that policymakers quantify the relative contributions of domestic and international shipping activities to these impacts in an integrated global analysis. A new study in the journal *Environmental Research Letters* provides that kind of analysis for the first time.

PODCAST **Climate projections with Sergey Paltsev (Climate Now)**

The Joint Program deputy director discusses climate projections and the tools he and his colleagues use to communicate projected outcomes to policymakers and the public

With the window to act narrowing, a stark report from the world's climate experts (Boston Globe)

Findings in latest UN IPCC report are alarming, says Paltsev

What can we do now to avert the worst climate impacts? (The Hill)

Paltsev explores potential responses to findings in the latest IPCC report

Regional Analysis

Science and policy studies at subnational, national and multinational levels

Scientists project increased risk to water supplies in South Africa this century due to rising temperatures and declining rainfall

Study underscores need for aggressive climate mitigation and adaptation policies to prevent future 'Day Zero' droughts in dry, populated regions around the world

A Joint Program-led study has produced modeled projections of 21st-century changes in seasonal surface air temperature and precipitation for South Africa. Presented in a study in the journal *Climatic Change*, these projections show how temperature and precipitation over three sub-national regions are likely to change under a wide range of global climate mitigation policy scenarios.

Can South Africa and other nations with similar climates avoid future "Day Zero" water shortages?

Focused on the U.S., the first version of the Joint Program's "risk triage" platform analyzes current risks to natural and managed resources, where these compound to create risk hotspots, and where to boost resilience.

Multi-Sector Dynamics

Potential tipping points and transition states of Earth and human systems

Is the continental U.S. headed for rapid changes in land use?

New study applies emerging analytic method to scope out potential tipping points

Under business-as-usual, low-pressure and high-pressure land-use scenarios, researchers project that over the next 30 years there will likely be no tipping points leading to rapid deforestation or abandonment of agricultural land in the continental U.S. Their projections show that historic trends for the region accelerate under high-pressure and dissipate under low-pressure scenarios.

MIT collaborates with Biogen on three-year, $7 million initiative to address climate, health and equity

New work within the Joint Program to establish a state-of-the-art integrated model of climate and health aimed at identifying targets that deliver climate and health co-benefits

"Evidence suggests that not all climate-related actions deliver equal health benefits, yet policymakers, planners and stakeholders traditionally lack the tools to consider how decisions in one arena impact the other," said C. Adam Schlosser, deputy director of the Joint Program. "Biogen's collaboration with the MIT Joint Program—and its support of a new distinguished Biogen Fellow who will develop the new climate/health model—will accelerate our efforts to provide decision makers with these tools."

New 'risk triage' platform pinpoints compounding threats to U.S. infrastructure

Modeling tool showcases emerging MIT Joint Program research focus on multi-sector dynamics

Focused on the continental U.S., the first version of the platform analyzes current risks related to water, land, climate, the economy, energy, demographics, health and infrastructure, and where these compound to create risk hotspots. This screening-level visualization tool allows users to examine risks, identify hotspots when combining risks, and solve complex problems at regional and local levels.

AGU Fall Meeting goes hybrid for 2021

MIT Joint Program researchers to present recent findings on global and regional change

This year's AGU Fall Meeting will take place in New Orleans and online on December 13 - 17. Among those researchers will be 14 co-authors of oral and poster presentations, and conveners of conference sessions, who are core members or affiliates of the Joint Program. Their presentations and sessions span multiple research focus areas, including Earth systems, policy scenarios and multi-sector dynamics.

New Research Projects

Global availability of waste CO_2 for fuels

Sponsor: FAA (via MIT ASCENT)
Leader: Sergey Paltsev
Duration: 1 year

The MIT ASCENT 1 team will apply MIT's Economic Projection and Policy Analysis (EPPA) Model to quantify the global availability of waste CO_2 (e.g., from power generation, steel production or cement production) under different economic and policy scenarios until 2050/2070. For calculating waste CO_2 availability, the team plans to leverage existing scenario setups developed at the Joint Program. Within these emission scenarios, waste CO_2 streams, which can be captured at reasonable cost, will be identified on the basis of a set of criteria which may include the scale of CO_2 emissions and CO_2 concentrations.

Using a data-constrained global-ocean ecology and biogeochemistry model to study the role of ocean circulation and the biological pump in driving ocean carbon cycle variability

Sponsor: NASA (via Jet Propulsion Laboratory)
Leader: Stephanie Dutkiewicz and Dimitris Menemenlis (JPL)
Duration: 3 years

This project will apply the Darwin ocean ecology model and ECCO-MITgcm estimates of ocean circulation to study the relationship between upper ocean community production, particulate organic carbon export fluxes, interior ocean remineralization, and biological carbon stores, and compare observations with biogeochemical budget computations.

Advancing methane biogeochemistry modeling with machine learning technique

Sponsor: Earl A Killian III and Waidy Lee MIT Seed Fund
Leader: Xiang Gao
Duration: 1.5 years

Methane (CH_4) accounts for up to 25% of atmospheric warming to date, but large uncertainty exists in methane emissions estimates from wetlands (the largest natural CH_4 source) using biogeochemistry models. This uncertainty arises largely because wetland CH_4 dynamics depend on a diverse array of poorly-represented physical, biological and chemical processes, as well as a large number of poorly-constrained uncertain parameters to characterize these processes. This project will examine the sensitivity of CH_4 emissions to a large set of parameters and optimize the most sensitive parameters, at observation sites covering a wide range of soil types, vegetation types and climatic conditions. The main goals are to provide insights into key parameters that drive uncertainty in wetland CH_4 emissions at each site and parameter transferability between sites; enhance the process-level understanding of mechanisms and controls underlying CH_4 biogeochemistry; and enable more reliable projections of the magnitude and variability of global and regional wetland CH_4 emissions under a changing climate.

The role of boreal wildfires in the global carbon budget: A process-based analysis using satellite-derived fire burn severity data

Sponsor: NASA (via Purdue University)
Leader: Ronald Prinn and Qianlai Zhang (Purdue)
Duration: 3 years

Atmospheric transport and inversion modeling will be used to assess the role of boreal forests affected by wildfires in the regional carbon budget and global atmospheric CO_2 concentrations. Orbiting Carbon Observatory CO_2 data and ecosystem model simulated carbon fluxes will be used as a prior for atmospheric inversions. The inversion surface atmospheric CO_2 will be evaluated with GlobalView data, while the posterior carbon fluxes will be evaluated to assess the role of boreal forests and wildfires in the regional carbon budget.

The impact of climate change on global health

Sponsor: Novartis
Leader: Adam Schlosser
Duration: 2 years

Existing climate targets neither consider nor identify the impact of successful pathways that also achieve an environment that supports and protects human health. In addition, we have limited knowledge of the landscape of various health risk drivers. This projects aims to assess the relative impact on health (of humans and nature) of global progress towards global temperature targets. Ultimately, these targets with be illustrated with analysis and visualization platforms of the health impacts across the nexus of nature's resources (i.e. air, water, energy, land) and infrastructure. The main goal is to build upon the Joint Program's multi-stressor risk-triage platform that will identify, quantify and project the risks from multiple environmental and human-based stressors, influences and impacts on human health as well as actions toward a more resilient and prosperous healthcare infrastructure.

Nature-based solutions for accelerating climate action

Sponsor: MIT International Science & Technology Initiatives (MISTI) Imperial College London Seed Fund
Leader: Sergey Paltsev and Joeri Rogelj (Imperial College London)
Duration: 1.5 years

Climate change solutions that have nature at their core, such as reforestation or ecosystem restoration, are increasingly touted as a way to address the climate and biodiversity crises. However, ecological, socio-technological and financial barriers may impede the implementation and upscaling of these nature-based solutions (NBS) in ways that benefit the environment and society. This project is dedicated to identifying how these cross-sectoral challenges can be surmounted. The MIT-Imperial College working group will identify the most important conceptual and practical knowledge gaps associated with the implementation of NBS.

NEW RESEARCH PROJECTS - CONT'D

Quantifying the opportunities for energy transition in hard-to-abate sectors: Decarbonizing cement and concrete

Sponsor: Shell (via MITEI)

Leader: Sergey Paltsev and Randolph Kirchain (MIT Concrete Sustainability Hub)

Duration: 1 year

Cement and concrete production and use are major contributors to overall emissions in sectors that are hard to decarbonize. In contrast to previous assessments that have explored strategies to reduce emissions from cement and concrete, this project's proposed framework will include technological detail and economic feedback to all activities globally and in particular regions. This framework for evaluating conventional and emerging technology solutions and their economic and environmental impacts will expand MIT tools and expertise to provide actionable guidance to both firms and policymakers on how best to reduce greenhouse gas emissions associated with cement and concrete production and use.

Milestones

MIT EAPS Professor **Susan Solomon** was one of three recipients of this year's Future of Life Award from the Future of Life Institute, which recognizes individuals who have made the world safer from existential or global catastrophic risks. Solomon and her fellow recipients were honored for their role in understanding and communicating about the depletion of the ozone layer—work that could help inform efforts to address the climate crisis.

MIT IDSS/EAPS Professor **Noelle Selin** was promoted to the rank of full professor effective July 1.

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(a) see p 3(a)
(b) see p 2
(c) see p 3(b)

Joint Program Reports

352. Toward resilient energy infrastructure: Understanding the effects of changes in the climate mean and extreme events in the Northeastern United States

353. Predictability of U.S. regional extreme precipitation occurrence based on large-scale meteorological patterns (LSMPs)

354. Distributional Impacts of Low-Carbon Policies in USA and Spain: Does One Size Fit All?

355. Economic Analysis of the Hard-to-Abate Sectors in India

Peer-Reviewed Studies

The changing nature of hydroclimatic risks across South Africa (*Clim Change*)

How predictable is plankton biogeography using statistical learning methods? (*Earth and Space Science Open Archive*)

Global cancer risk from unregulated polycyclic aromatic hydrocarbons (*GeoHealth*)

Climate effects on US infrastructure: the economics of adaptation for rail, roads, and coastal development (*Clim Change*)

Global health effects of future atmospheric mercury emissions (*Nature Comm*)

Hard-to-abate sectors: The role of industrial carbon capture and storage (CCS) in emission mitigation (*Applied Energy*)

Global air quality and health impacts of domestic and international shipping (*Environ Res Lett*)

The cost of CO_2 transport and storage in global integrated assessment modeling (*Int'l J of GHG Control*)

Predictability of U.S. regional extreme precipitation occurrence based on large-scale meteorological patterns (LSMPs) (*J Climate*)

Nexus versus Silo investment planning under uncertainty (*Frontiers in Water*)

Future phytoplankton diversity in a changing climate (*Nature Comm*)

Lessons from a pandemic for systems-oriented sustainability research (*Sci Adv*)

Global health effects of future atmospheric mercury emissions (*Nature Comm*)

Abrupt shifts in 21st-century plankton communities (*Sci Adv*)

Sustained methane emissions from China after 2012 despite declining coal production and rice-cultivated area (*Environ Res Lett*)

Moving ecological and biogeochemical transitions across the North Pacific (*Limnology and Oceanography*)

Global Electrification of light-duty vehicles: Impacts of economics and climate policy (*Econ of Energy & Environ Pol*)

Challenges in simulating economic effects of climate change on global agricultural markets (*Clim Change*)

MIT JOINT PROGRAM ON THE SCIENCE AND POLICY of GLOBAL CHANGE

Our work 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.

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