

The Infrastructure and Climate Network (ICNet)

What climate data, model output, and information do engineers want & need?



Principals: Jennifer Jacobs, UNH, Jo Daniel, UNH, Ellen Douglas, UMB, Lee Friess, ICNet, Jack Kartez, USM, Paul Kirshen, UMB, Katharine Hayhoe, TTU, Linda Silka, UMaine

Contact Us: icnet@theICNet.org, Follow Us: theICNet.org; Tweet Us: [#ICNetNE](https://twitter.com/ICNetNE)

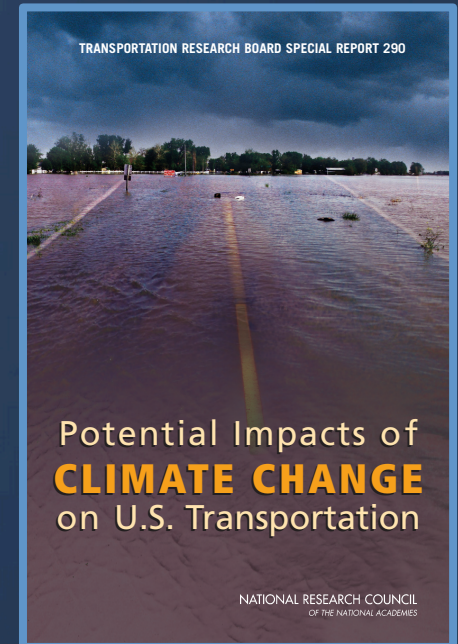


What is the ICNet?

Networks 100+ academics, students, & practitioners who are dedicated to accelerating climate science and transportation engineering research and adaptation in the Northeastern United States.

Focuses on climate change and sea level rise impacts research and adaptation for sustainable bridges, roads, railways, ports, and transportation networks.

Supported by the National Science Foundation since 2012



TRB Special Report 290, 2008



Motivation & Implications

The U.S. spends nearly **\$200,000,000** per day building and rebuilding roads and bridges

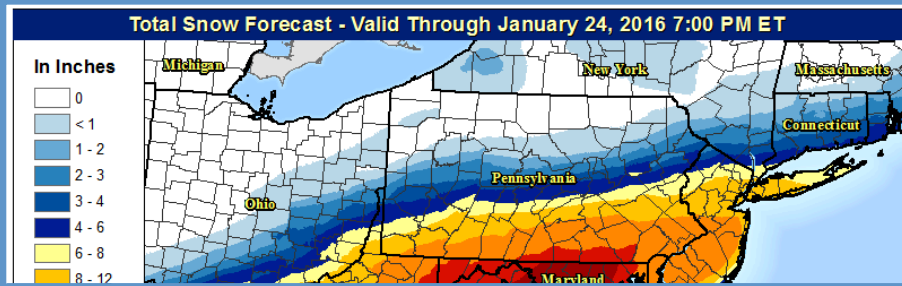
Driving delays are expected to waste **7.3 billion gallons of fuel** per year over the next two decades, increasing travelers' costs by **\$41,000,000,000**, and add **73 million tons** of carbon dioxide to the atmosphere.

Climate and weather an important consideration in major road and bridge **planning, design, and operations & maintenance**

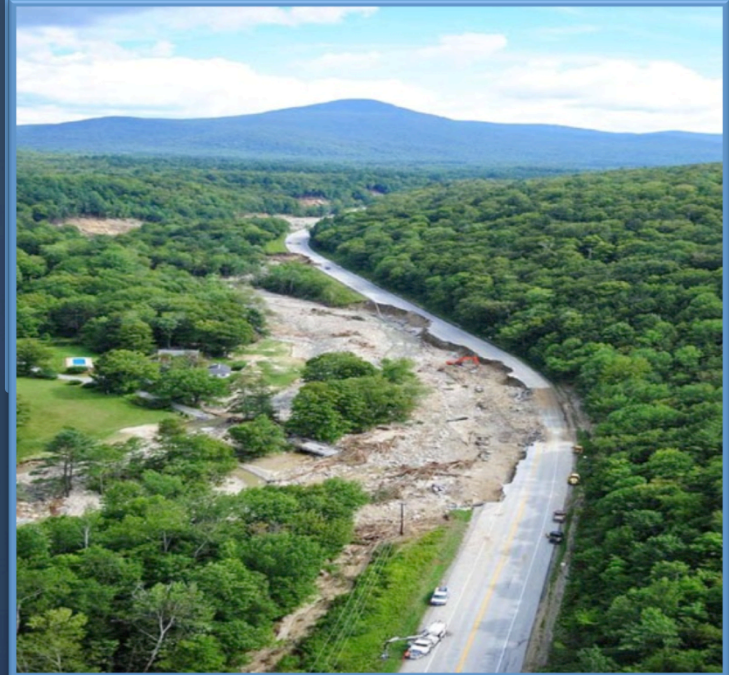
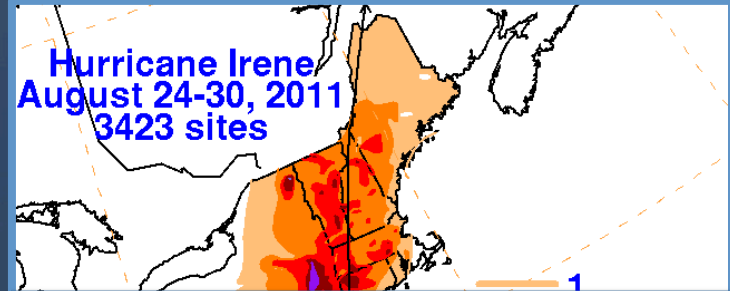
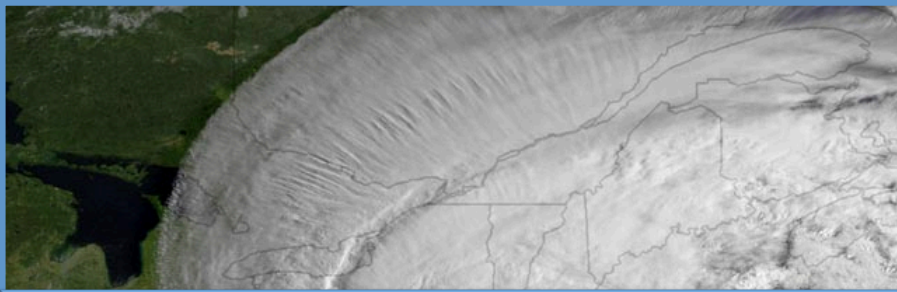
Very little information exists to guide roadway and bridge practitioners in light of climate change



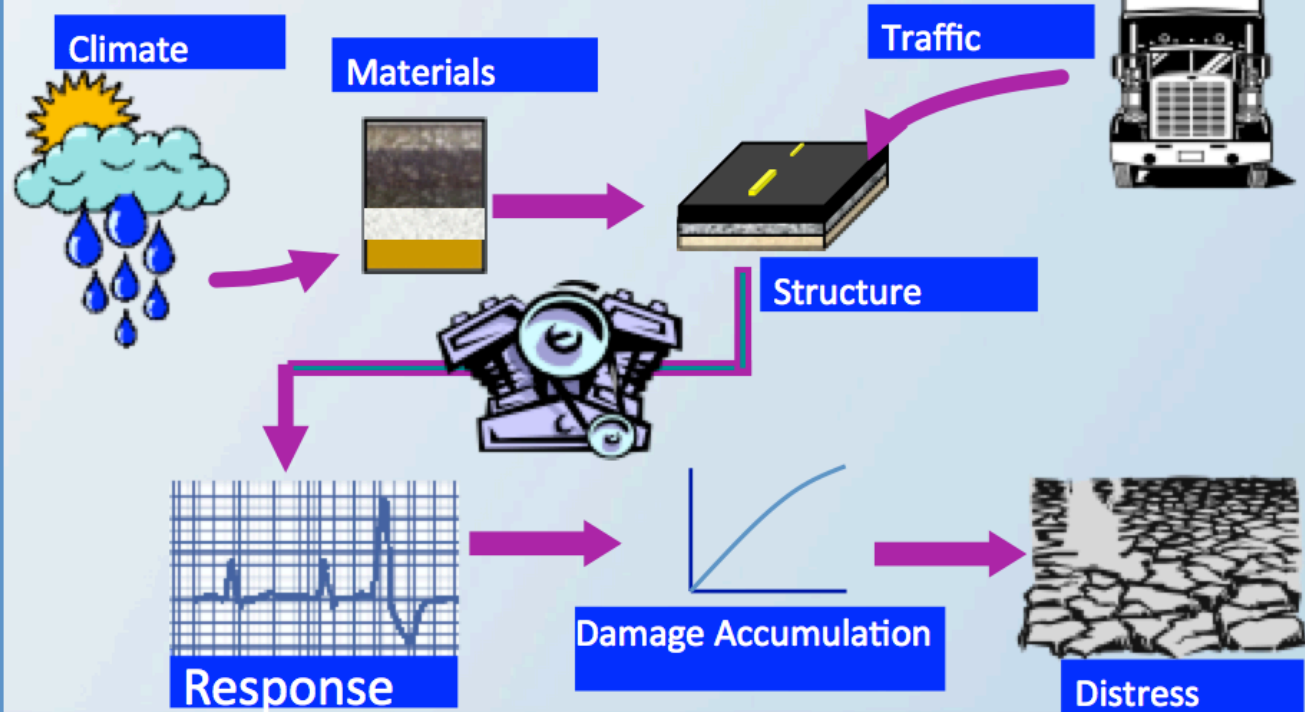
Extreme Events: Winter Storm "Jonas" January 21-24, 2016



Extreme Weather Events: Hurricane Irene August 24-30, 2011



Climate Impacts: Pavement Rutting



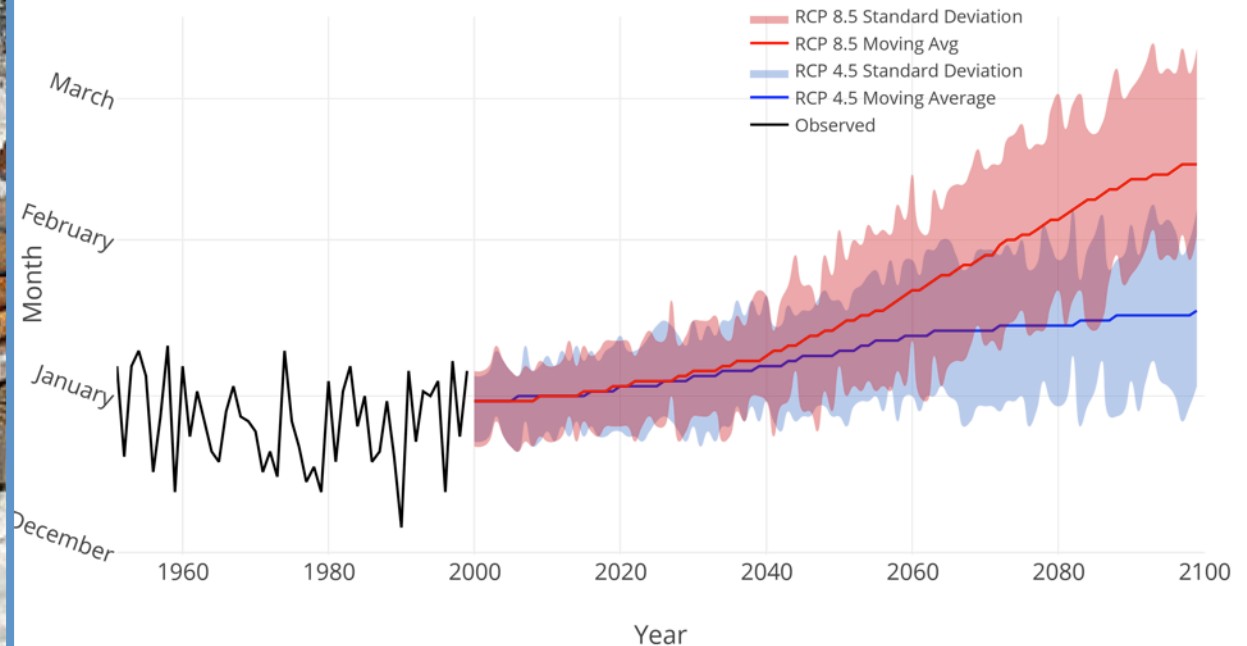
University of
New Hampshire

Climate Impacts: Freeze-Thaw and Roads

Frozen Soils Increase Road Strength and Stiffness



Date to apply winter weight premium in Madison, ME



Climate Change and Infrastructure

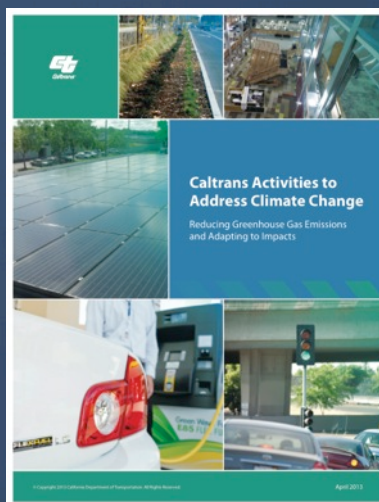
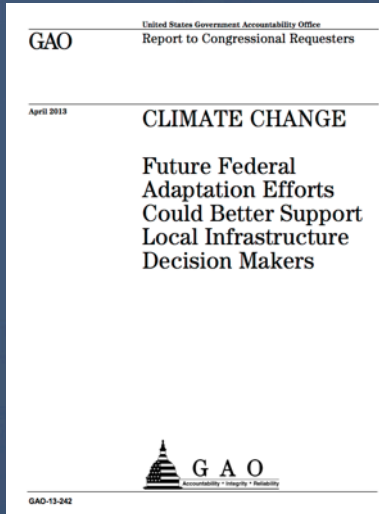
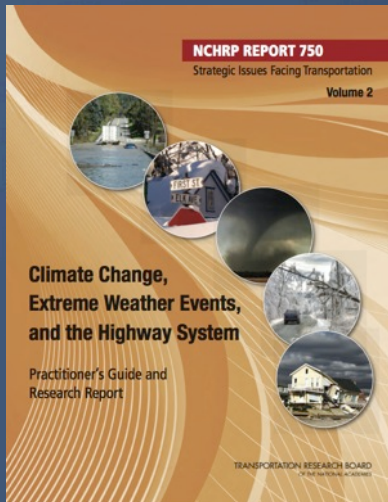
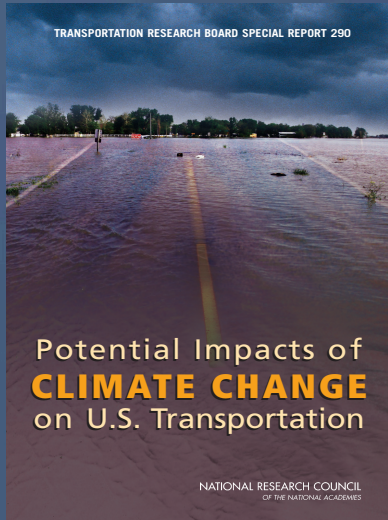
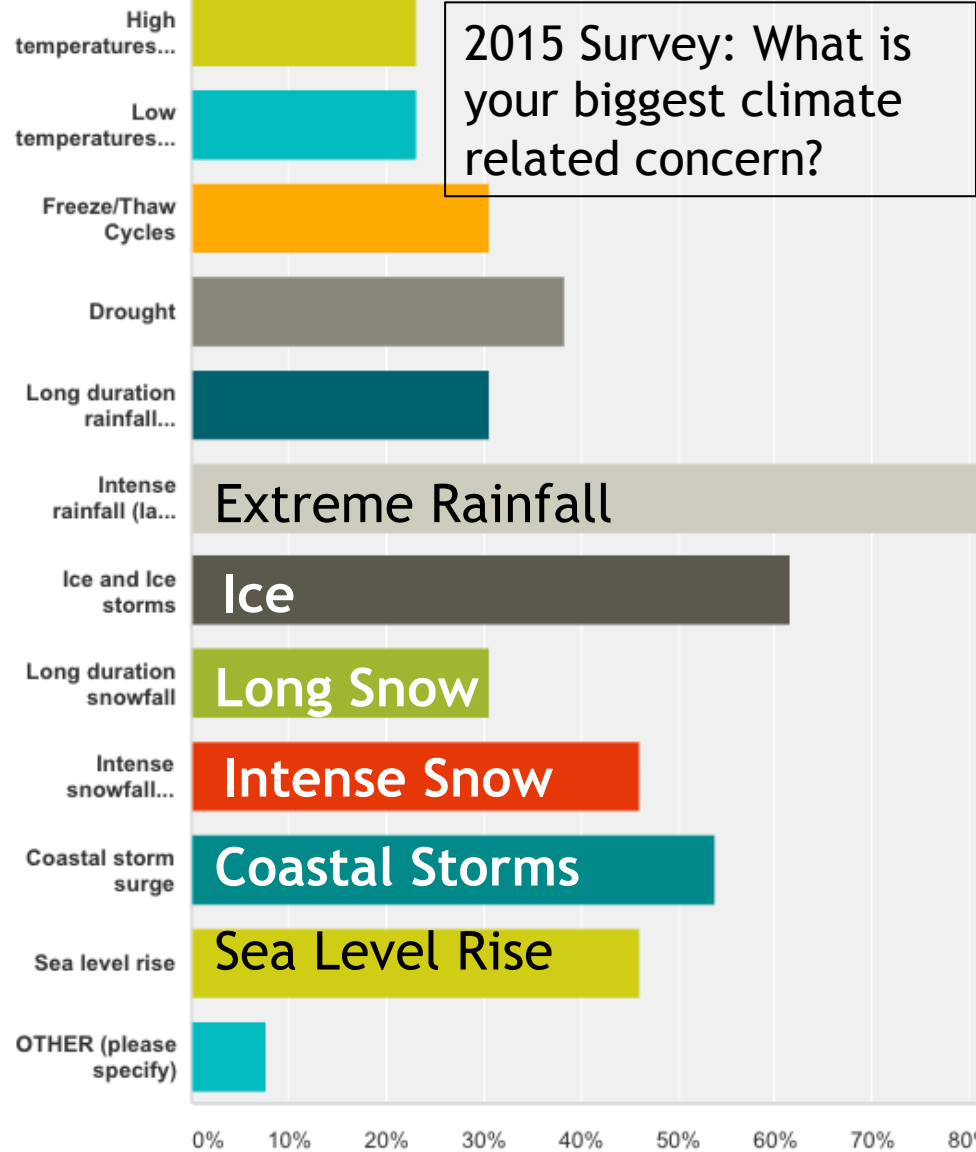


Table 12. Sea Level Rise Impacts on Surface Transportation

Impact	Planning	Design	Operation/Maintenance
Sea Level Rise			
<p>Coastal Erosion</p> <ul style="list-style-type: none"> Coastal erosion Roadway washout Damage to roadway substructure Route closures Travel delays 	<ul style="list-style-type: none"> Identify segments of roadway vulnerable to erosion Address vulnerability in transportation plans 	<ul style="list-style-type: none"> Strengthen, heighten, and construct new seawalls and dikes Use a combination of hard engineering (human-made structures) and soft engineering measures (implementing ecological principles and practices) to protect coastal infrastructure Relocate highly affected or vulnerable infrastructure 	<ul style="list-style-type: none"> Repair damage as needed by emergency contract or permanent restoration project Increase monitoring of infrastructure and conditions in coastal areas vulnerable to erosion Repair/replace/restore affected infrastructure as needed Increase erosion control Prepare for weather-related delays and traffic disruptions Prepare to provide alternative route information
<p>Flooding</p> <ul style="list-style-type: none"> Coastal and inland tidal zone road flooding Flooding of roadways Roadway damage Road closures Travel delays Disruption of transit services 	<ul style="list-style-type: none"> Identify segments of roadway vulnerable to storm surge and sea level rise Address vulnerability in transportation plans Support land use policies that discourage development on shoreline Plan and design more redundancy into the system 	<ul style="list-style-type: none"> Increase base elevation of infrastructure Change to more resilient building materials Build larger or additional drainage canals near coastal routes Relocate sections of road Strengthen, heighten, and construct new seawalls and dikes Use a combination of hard engineering (human-made structures) and soft engineering measures (implementing ecological principles) to protect coastal infrastructure 	<ul style="list-style-type: none"> Repair damage as needed by emergency contract or permanent restoration project Increase monitoring of infrastructure conditions during high tide and storm events Ensure that drainage systems are adequate to accommodate flood conditions Ensure that bridge openings/culverts are clear for appropriate flood management During extreme precipitation events, continually monitor drainage systems Prepare for weather-related delays and traffic disruptions Prepare to provide alternative route information Implement emergency operations response procedures
<p>Bridge Scour</p> <ul style="list-style-type: none"> Bridge scour Compromised integrity of bridge structures Bridge failure resulting in closure Reduced bridge capacity 	<ul style="list-style-type: none"> Identify locations of bridges in areas vulnerable to sea level rise and bridge scour Address vulnerabilities in transportation plans 	<ul style="list-style-type: none"> Protect bridge piers and abutments with riprap Retrofit/replace/relocate existing bridges for new scour conditions 	<ul style="list-style-type: none"> Repair damage as needed by emergency contract or permanent restoration project Increase monitoring for bridge pier and abutment scour



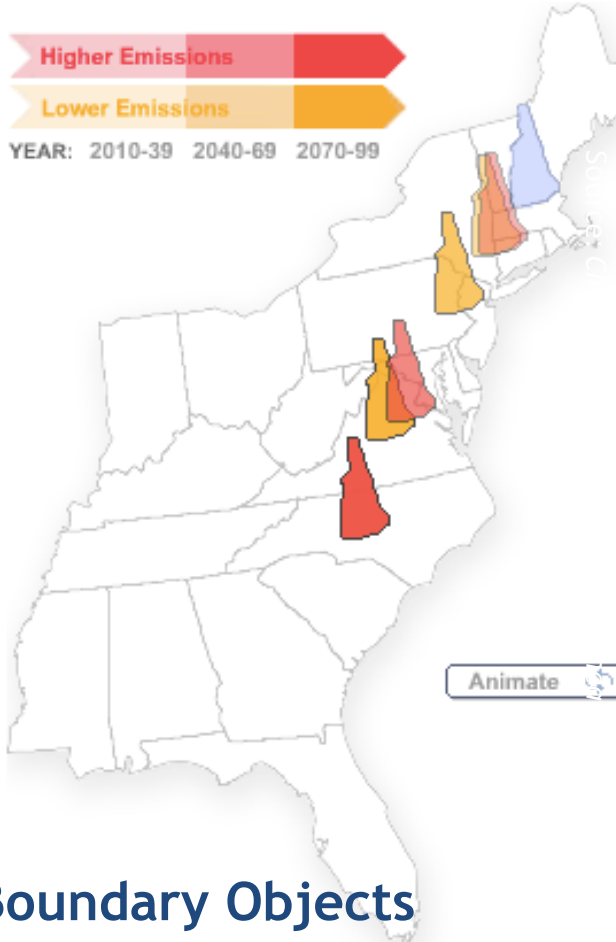
Eastern Region Department of Transportation Concerns



ICNet Foundation Tools

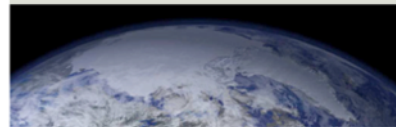
Higher Emissions
Lower Emissions

YEAR: 2010-39 2040-69 2070-99



Boundary Objects

ICNet Webinar Series http://theicnet.org/?page_id=24



HIGH-RESOLUTION CLIMATE PROJECTIONS

I know I need them – but which ones should I use?

KATHARINE HAYHOE, Texas Tech University

CLIMATE CHANGE IN THE NORTHEAST US: PAST, PRESENT, AND FUTURE

Cameron Wake
Climate Solutions New England
Institute for the Study of Earth, Oceans, and Space (EOS)
University of New Hampshire
@TheClimateDr

Infrastructure and Climate Network (ICNet) Webinar
9 October 2013
TheICNet.org #ICNetNE

Coping with Climate Change at MAINE DOT

Charles Hebson & Judy Gates
Environmental Office

presented for
ICNet Webinar
26 March 2014

FHWA Efforts with Respect to Resilience in Operations and Maintenance

Laurel Radow
Office of Operations
Federal Highway Administration

ICNet Webinar – April 21, 2015



Transportation Community Climate Indicators

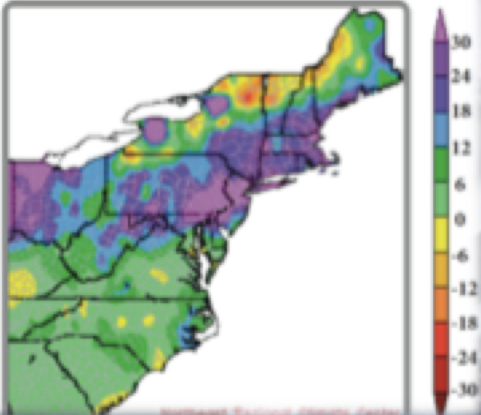
Precipitation

- Annual Average
- Spring Average
- Summer Average
- Fall Average
- Winter Average
- Days per year over 2 in.
- Days per year over 3 in.
- Maximum daily
- Maximum weekly

Temperature

- Annual Average
- Spring Average (MIN & MAX)
- Summer Average (MIN & MAX)
- Fall Average (MIN & MAX)
- Winter Average (MIN & MAX)
- Maximum
- Minimum
- Days over 95°F

Departure from Normal Snowfall (in.)
December 1, 2013–February 28, 2014



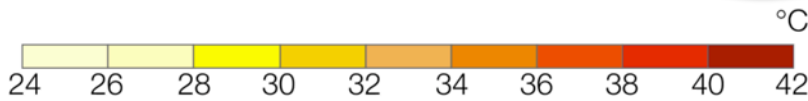
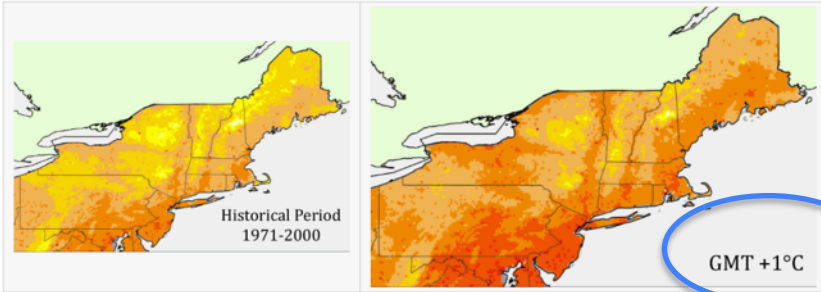
Olympian Drive, Champaign, IL: Buckling of pavement during extreme heat. Image: The Champaign-Urbana News Gazette

ICNet Climate Maps

Referenced to Global Mean Temp

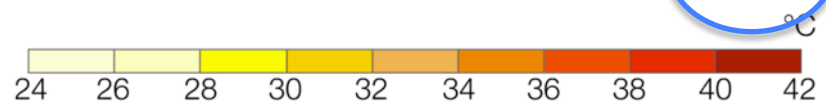
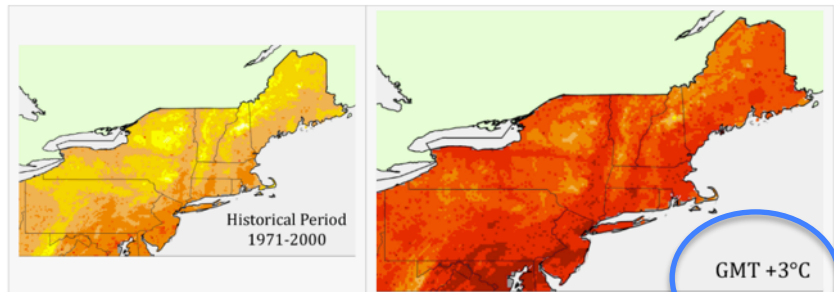
Maximum Temperature (°C)

GMT +1°C GMT +2°C GMT +3°C



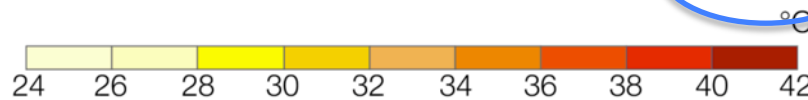
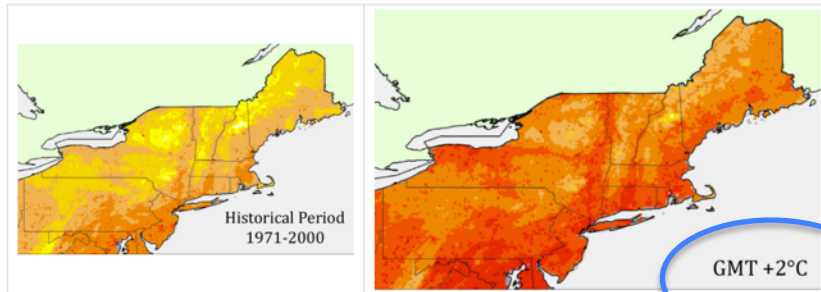
Maximum Temperature (°C)

GMT +1°C GMT +2°C GMT +3°C

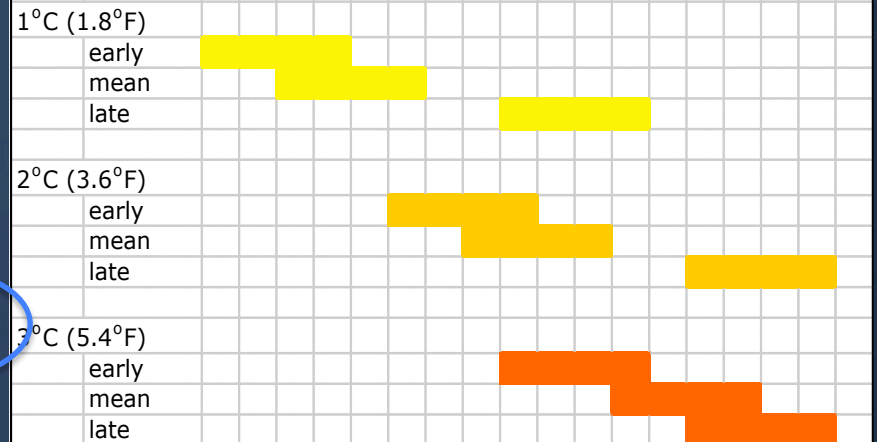


Maximum Temperature (°C)

GMT +1°C GMT +2°C GMT +3°C



Global Mean T* 2010s 2020s 2030s 2040s 2050s 2060s 2070s 2080s 2090s



*increase since 1971-2000 average

ICNet Research Grade Tools

Climate Model Comparison Tool

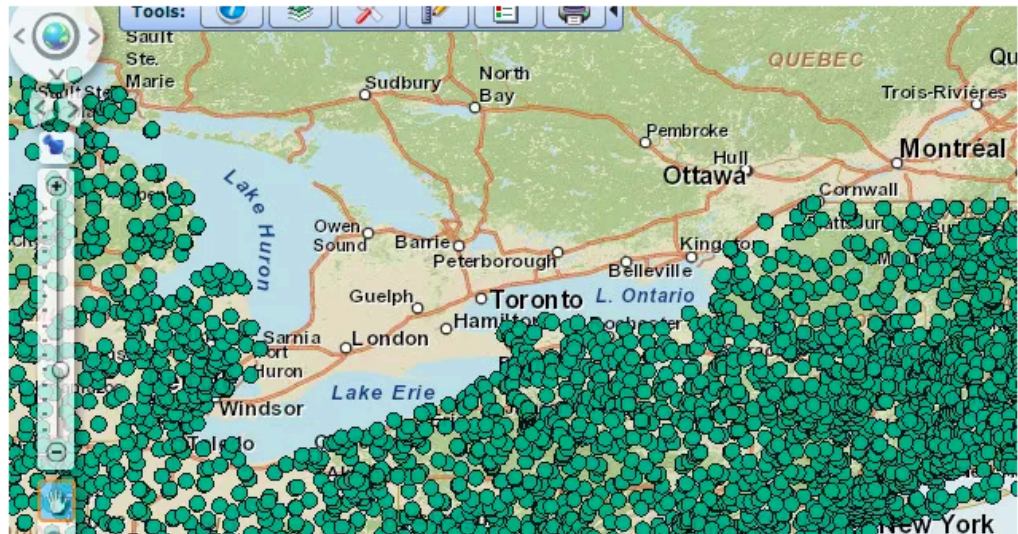
Resources

Choosing Climate Models

- Statistically Downscaled Output: [download the Excel file](#)
- Regional Model Output: [download the Excel file](#)
- Observational DataSets: [download Excel file](#)
- Station Observation Data: [visit the NOAA website](#)

Climate Model Intercomparison Project

- About CMIP: [visit the CMIP website](#)
- Raw Output for CMIP3 and CMIP5: [download the Excel file](#)



theICNet.org

Climate Model Output Source & Selection

The screenshot shows an Excel spreadsheet with the following content:

CMIP5 (Coupled Model Intercomparison Project version 5)

All CMIP5 model output can be downloaded at (registration required) <http://cmip-pcmdi.llnl.gov/cmip5/>

Appropriate applications: There is no *perfect* model, always use a selection of at least 4 different GCMs, the more GCMs included, the better. Do not attempt to select a *best* model for the region of interest. If using multiple climate model simulations for an analysis, always average across climate models as the very last step in the analysis. Do not average across multiple emission scenarios. In this case, averaging will NOT improve the quality of the output because scenarios are entirely different possibilities of future development. There is no one most likely emissions scenario. A good practice is to include a low and high scenario in the analysis to encompass the highest range in uncertainty.

Inappropriate applications: Selecting one single model and/or one single future scenario for analysis. Do not expect a downscaled climate simulation to match day-to-day observations. Climate projections are intended to match observations over climate time scales of decades, not days.

Types of models (column F):

- Group 1: MOST RELIABLE. Models in this group represent the most recent versions of reliable, very well-documented, long-established global climate models from modeling groups that have a long history of climate modeling.
- Group 2: NEW AND INTERESTING. The latest work in climate modeling circles is the development of "Earth System Models" that combine the traditional components of a global climate model with a representation of the human system. These models can definitely be used for interest but should have a "caution" label attached as they are still very much in development.
- Group 3: EXPERIMENTAL. Models in this group represent brand-new global climate models, some from new modeling groups who are relatively inexperienced in the field. These models have not been used for a long time and others come from new groups and clearly need some time to sort out some inconsistencies in the models. Again, they should be used with a "caution" label attached.

Model Name	Modeling Center	Modelling Group	Country	Reference	Model Type (1, 2, or 3)	Data Format
ACCESS1.0	CSIRO-BOM	Commonwealth Scientific and Industrial Research Organisation and Bureau of Meteorology	Australia	Bi et al., 2013	3	netCDF
ACCESS1.3	CSIRO-BOM	Commonwealth Scientific and Industrial Research Organisation and Bureau of Meteorology	Australia	Bi et al., 2013	3	netCDF
BCC-CSM1.1	BCC	Beijing Climate Center, China Meteorological Administration	China	Wu, 2012	1	netCDF
BCC-CSM1.1-m	BCC	Beijing Climate Center, China Meteorological Administration	China	Wu, 2012	1	netCDF
		College of Global Change and Earth System Science, Beijing				

Application of Climate Model Output

The ICNet Research Guide

About the Guide

Background Information

[The Basics of Climate Change](#)

[Introduction to Climate Models](#)

[The Intersection of Climate Change and Infrastructure](#)

New to Research

[Research Basics](#)

[Introduction to Pilot Studies](#)

[Conduct a Pilot Study](#)

[Plan and Begin a Study](#)

[A Guide to Infrastructure and Climate Change Pilot Studies](#)

[A Guide to Infrastructure and Climate Change Research](#)

Need research help?

The ICNet Research Guide

About this guide

This guide contains introductory information and specific methods for understanding and conducting research at the interface of climate change and transportation infrastructure. It is designed to be accessible for professionals and academics in the transportation or climate science sectors. It could also serve as an introduction for graduate and undergraduate students to the issues in climate science and transportation engineering. The Infrastructure and Climate Network (ICNet) created this guide for its members and others interested in advancing research on climate and infrastructure. More [about the ICNet](#).

Why is climate change and infrastructure research important?

Our infrastructure is built on the assumption that the climate will stay stable, water levels along shore roads will remain consistent, and bridges will be subjected to floods with known levels and frequencies. The 2014 Intergovernmental Panel on Climate Change, among other scientific organizations, has reported that the climate is warming, in large part due to human activity. Increasing temperatures, precipitation, and rising sea levels will affect our roads, bridges, and other transportation infrastructure, with implications for public safety and the economy. Accurate, relevant scientific information is needed to effectively plan and design resilient infrastructure for communities now and in the future.

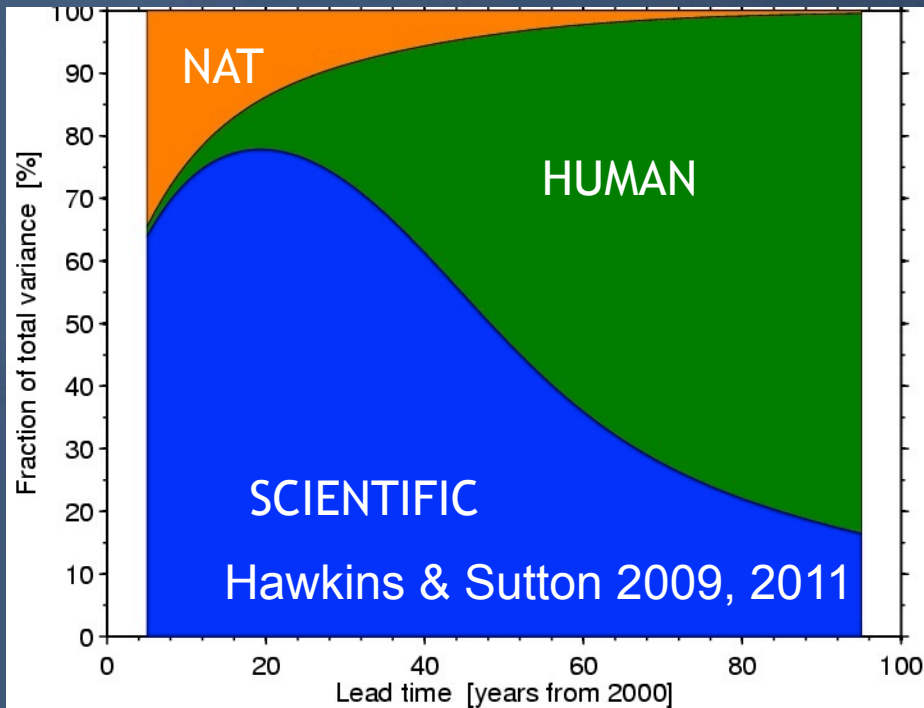


University of
New Hampshire

Methods to Characterize Uncertainty

Relative Importance by Source

Climate Models & Observations:
Global Temperature



Transportation: Planning,
Design, Operations &
Maintenance

- Materials
- Design Guides
- Performance Models

Priority Upcoming Climate Data & Products Needs

- *Flooding Standards & Climate Change*
- *Uncertainty Quantification*
- *Linking DOT Assets & Weather/Climate*

DOT Asset Management



The White House
Office of the Press Secretary

For Immediate Release

January 30, 2015

Executive Order – Establishing a Federal Flood Risk Management Standard and a Process for Further Soliciting and Considering Stakeholder Input

EXECUTIVE ORDER

ESTABLISHING A FEDERAL FLOOD RISK MANAGEMENT STANDARD
AND A PROCESS FOR FURTHER SOLICITING AND CONSIDERING
STAKEHOLDER INPUT

By the authority vested in me as President by the Constitution and the laws of the United States of America, and in order to improve the Nation's resilience to current and future flood risk, I hereby direct the following:

Section 1. Policy. It is the policy of the United States to improve the resilience of communities and Federal assets against the impacts of flooding. These impacts are anticipated to increase over time due to the effects of climate change and other threats. Losses caused by flooding affect the environment, our economic prosperity, and public health and safety, each of which affects our national security.

The Federal Government must take action, informed by the best-available and actionable science, to improve the Nation's preparedness and resilience against flooding. Executive Order 11988 of May 24, 1977 (Floodplain Management), requires executive departments and agencies (agencies) to avoid, to the extent possible, the long- and short-term adverse impacts associated with the occupancy and modification of floodplains and to avoid direct or indirect support of floodplain development wherever there is a practicable alternative. The Federal Government has developed processes for evaluating the impacts of Federal actions in or affecting floodplains to implement Executive Order 11988.



Please use ICNet resources, contact ICNet, join ICNet, & refer peers to ICNet

ICNet 4th Annual Workshop
April 11 and 12, 2016
New Castle, NH



Contact Us: icnet@theICNet.org, Follow Us: theICNet.org; Tweet Us: [#ICNetNE](https://twitter.com/ICNetNE)



University of
New Hampshire

Thank you

For more information, please visit theicnet.org or contact
Jennifer Jacobs: Jennifer.Jacobs@unh.edu

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