The Infrastructure and Climate Network (ICNet)

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

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Contact Us: icnet@theICNet.org, Follow Us: theICNet.org; Tweet Us: #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

Potential Impacts of CLIMATE CHANGE on U.S. Transportation

This National Research Council report presents an overview of the scientific consensus about the current and future climate changes affecting U.S. transportation, including the limits of scientific understanding of the timing, magnitude, and location of the effects; identifies the potential impacts on U.S. transportation and the options for adaptation; and recommends research and actions to prepare for climate change. The report also summarizes previous work on strategies for reducing the transportation-related emissions of carbon dioxide—the primary greenhouse gas—which contribute to climate change.
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
Climate Impacts: Pavement Rutting

- Climate
- Materials
- Traffic
- Structure
- Response
- Damage Accumulation
- Distress
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

Potential Impacts of CLIMATE CHANGE on U.S. Transportation

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Table 12. Sea Level Rise Impacts on Surface Transportation

<table>
<thead>
<tr>
<th>Impact</th>
<th>Planning</th>
<th>Design</th>
<th>Operation/Maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coastal erosion</td>
<td>Roadway washout, damage to roadway substructure, route closures, travel delays</td>
<td>- Strengthen, heighten, and construct new seawalls and dikes</td>
<td>- Repair damage as needed by emergency contract or permanent restoration project</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Use a combination of hard engineering (human-made structures) and soft engineering measures (implementing ecological principles and practices) to protect coastal infrastructure</td>
<td>- Increase monitoring of infrastructure and conditions in coastal areas vulnerable to erosion</td>
</tr>
<tr>
<td>Coastal and inland tidal zone road flooding</td>
<td>- Flooding of roadways, roadway damage, road closures, travel delays, disruption of transit services</td>
<td>- Identify segments of roadway vulnerable to storm surge and sea level rise</td>
<td>- Repair and replace/restored affected infrastructure as needed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Increase base elevation of infrastructure, change to more resilient building materials</td>
<td>- Prepare for weather-related delays and traffic disruptions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Build larger or additional drainage canals near coastal routes, relocate sections of road, support land use policies that discourage development on shoreline</td>
<td>- Prepare to provide alternative route information</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Support land use policies that discourage development on shoreline, plan and design more redundancy into the system</td>
<td>- Implement emergency operations response procedures</td>
</tr>
<tr>
<td>Bridge scour</td>
<td>- Compromised integrity of bridge structures, bridge failure resulting in closure, reduced bridge capacity</td>
<td>- Identify locations of bridges in areas vulnerable to sea level rise and bridge scour</td>
<td>- Repair damage as needed by emergency contract or permanent restoration project</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Protect bridge piers and abutments with riprap, retrofit/replace/relocate existing bridges for new scour conditions</td>
<td>- Increase monitoring for bridge pier and abutment scour</td>
</tr>
</tbody>
</table>

Coastal Erosion

Flooding

Bridge Scour
<table>
<thead>
<tr>
<th>Concern</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extreme Rainfall</td>
<td>30%</td>
</tr>
<tr>
<td>Ice</td>
<td>40%</td>
</tr>
<tr>
<td>Long Snow</td>
<td>25%</td>
</tr>
<tr>
<td>Intense Snow</td>
<td>15%</td>
</tr>
<tr>
<td>Coastal Storms</td>
<td>10%</td>
</tr>
<tr>
<td>Sea Level Rise</td>
<td>0%</td>
</tr>
</tbody>
</table>

2015 Survey: What is your biggest climate related concern?
ICNet Foundation Tools

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

Coping with Climate Change at MaineDOT
Charles H. B. & 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
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

Olympian Drive, Champaign, IL: Buckling of pavement during extreme heat. Image: The Champaign-Urbana News Gazette
Global Mean T* 1°C (1.8°F) increase since 1971-2000 average

ICNet Climate Maps
Referenced to Global Mean Temp

Maximum Temperature (°C)

<table>
<thead>
<tr>
<th>GMT +1°C</th>
<th>GMT +2°C</th>
<th>GMT +3°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>24</td>
<td>26</td>
<td>28</td>
</tr>
<tr>
<td>28</td>
<td>30</td>
<td>32</td>
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<td>32</td>
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<td>36</td>
<td>38</td>
<td>40</td>
</tr>
<tr>
<td>40</td>
<td>42</td>
<td></td>
</tr>
</tbody>
</table>

Historical Period 1971-2000

GMT +1°C

GMT +2°C

GMT +3°C

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

1°C (1.8°F)
- early
- mean
- late

2°C (3.6°F)
- early
- mean
- late

3°C (5.4°F)
- early
- mean
- late

*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
# 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 a few months.

### Types of models (column F):

<table>
<thead>
<tr>
<th>Group</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>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 participated in all CMIP projects.</td>
</tr>
<tr>
<td>Group 2</td>
<td>NEW AND INTERESTING. The latest work in climate modeling circles is the development of &quot;Earth System Models&quot; that combine the traditional components of a global climate model. Once models can definitely be used for interest but should have a &quot;caution&quot; label attached as they are still very much in development.</td>
</tr>
<tr>
<td>Group 3</td>
<td>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 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 &quot;caution&quot; label attached.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Model Name</th>
<th>Modeling Center</th>
<th>Modelling Group</th>
<th>Country</th>
<th>Reference</th>
<th>Model Type (1, 2, or 3)</th>
<th>Data Formats</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACCESS1.0</td>
<td>CSIRO-BOM</td>
<td>Commonwealth Scientific and Industrial Research Organisation and Bureau of Meteorology</td>
<td>Australia</td>
<td>Bl et al., 2013</td>
<td>3</td>
<td>netCDF</td>
</tr>
<tr>
<td>ACCESS1.3</td>
<td>CSIRO-BOM</td>
<td>Commonwealth Scientific and Industrial Research Organisation and Bureau of Meteorology</td>
<td>Australia</td>
<td>Bl et al., 2013</td>
<td>3</td>
<td>netCDF</td>
</tr>
<tr>
<td>BCC-CSM1.1</td>
<td>BCC</td>
<td>Beijing Climate Center, China Meteorological Administration</td>
<td>China</td>
<td>Wu, 2012</td>
<td>1</td>
<td>netCDF</td>
</tr>
<tr>
<td>BCC-CSM1.1m</td>
<td>BCC</td>
<td>Beijing Climate Center, China Meteorological Administration</td>
<td>China</td>
<td>Wu, 2012</td>
<td>1</td>
<td>netCDF</td>
</tr>
</tbody>
</table>

[![Climate Model Output Source & Selection](image)](image)
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.
Methods to Characterize Uncertainty Relative Importance by Source

Climate Models & Observations: Global Temperature

Transportation: Planning, Design, Operations & Maintenance
- Materials
- Design Guides
- Performance Models

Hawkins & Sutton 2009, 2011
Priority Upcoming Climate Data & Products Needs

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

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**DOT Asset Management**

- National Goals
- Performance Measures
- Performance Targets
- Performance Plans
- Target Achievement
- Special Performance Rules Apply
- Targets set by States & MPOs

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**MAP-21**

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**The White House**
Office of the Press Secretary
For Immediate Release January 30, 2016

**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
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Special thanks to Ellen Mecray, NOAA for her service to ICNet

Thank you

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