Transportation and Climate Change Resource Center

REAL SOLUTIONS FOR CLIMATE CHANGE

Climate Adaptation for Transportation

MARCH 31, 2010

Presented by:

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Overview

I. What is adaptation?

II. Why should transportation agencies by interested?

III. Some examples

IV. Massachusetts example

V. Climate adaptation planning for transportation

VI. FHWA overview

VII. Resources

I. What is Adaptation?

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Adaptation per the Pew Center on Global Climate Change

"Actions by individuals or systems to avoid, withstand, or take advantage of current and projected climate changes and impacts. Adaptation decreases a system's vulnerability, or increases its resilience to impacts."

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Extreme Events

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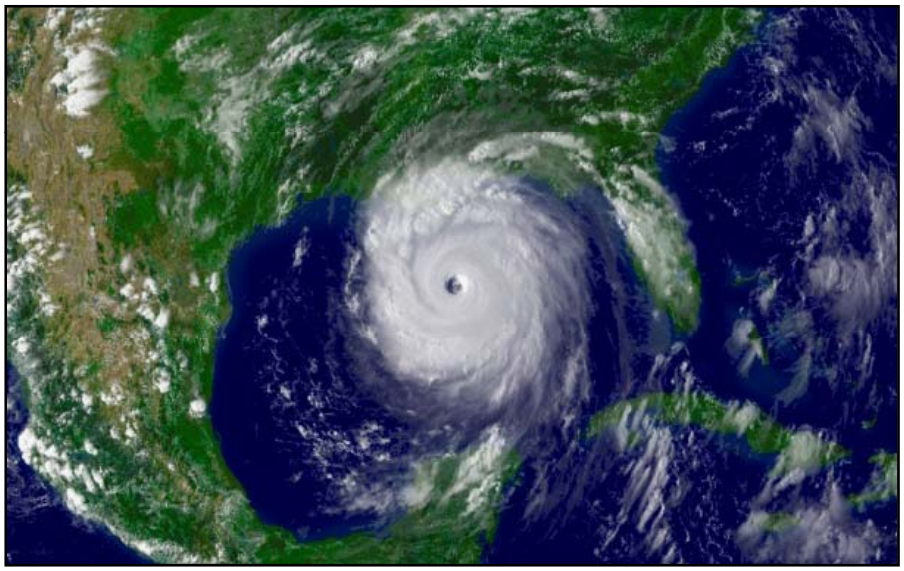

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Long-term Environmental Changes

Important to Note…..

Although many think coastal states are most at risk, non-coastal states need to think about temperature variations, more intense storms/runoffs, flooding, higher winds and ecological changes, depending on the context for each state.

II. Why should transportation agencies be interested?

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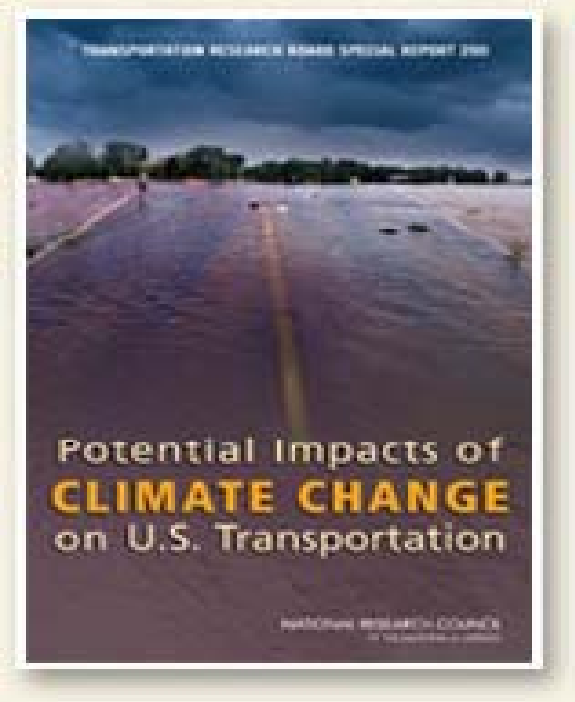

Potential Impact of Climate Change on U.S. Transportation

Transportation Research Board
Division on Earth & Life Studies
National Research Council

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"The past several decades of historical regional climate patterns … may no longer be a reliable guide for future plans. In particular, future climate will include new classes (in terms of magnitude and frequency) of weather and climate extremes … not experienced in modern times as human-induced changes are superimposed on the climate's natural variability."

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- Climate change will affect every mode of transportation and every region of U.S.
- Climate change considerations for long-term capital programs, facility designs, maintenance practices, operations and emergency response plans.
- Design standards
- Transportation planning (timeframes)
- Institutional arrangements for planning and operations

TRB Board Special Report 290

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- Increases in very hot days and heat waves (very likely)
- Increases in Arctic temperatures (virtually certain)
- Rising sea levels (virtually certain)
- Increases in intense precipitation events (very likely)

  and

- Increases in hurricane intensity (likely)

Possible Implications to Design

Climate-Change Phenomenon	Change in Environmental Condition	Design Implications

Possible Implications to Design

Climate-Change Phenomenon	Change in Environmental Condition	Design Implications
Temperature change	Rising maximum temperature; lower minimum temperature; wider temperature range; possible significant impact on permafrost	Over the short term*, minimal impact on pavement or structural design; potential significant impact on road, bridge scour and culvert design in cold regions Over the long term, possible significant impact on pavement and structural design; need for new materials; better maintenance strategies

Possible Implications to Design

Climate-Change Phenomenon	Change in Environmental Condition	Design Implications
Changing precipitation levels	Worst case scenario, more precipitation; higher water tables; greater levels of flooding; higher moisture content in soils	Over the short term, could affect pavement and drainage design; greater attention to foundation conditions; more probabilistic approaches to design floods; more targeted maintenance Over long term, definite impact on foundation design and design of drainage systems and culverts; design of pavement subgrade and materials impacts

Possible Implications to Design

Climate-Change Phenomenon	Change in Environmental Condition	Design Implications
Wind loads	Stronger wind speeds and thus loads on bridge structures; more turbulence	Over the short term, design factors for design wind speed might change; wind tunnel testing will have to consider more turbulent wind conditions Over the long term, greater materials strength and design considerations for suspended and cable-stayed bridges

Possible Implications to Design

Climate-Change Phenomenon	Change in Environmental Condition	Design Implications
Storm surges and greater wave height	Larger and more frequent storm surges; more powerful wave action	Over short term, design changes to bridge height in vulnerable areas; more probabilistic approach to predicting storm surges Over long term, design changes for bridge design, both superstructure and foundations; change in materials specifications; more protective strategies for critical components

Maintenance and Operations, example

- Change in weight restrictions
- Change in construction season
- Closures and detours
- Speed reductions
- Drainage erosion
- Grass cutting/snow plowing

Key “Transportation” Messages from US Global Change Research Program

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- Sea-level rise and storm surge will increase the risk of … both temporary and permanent flooding of airports, roads, rail lines, and tunnels.
- Flooding from increasingly intense downpours will increase the risk of disruptions and delays in air, rail, and road transportation, and damage from mudslides in some areas.
- The increase in extreme heat will limit some transportation operations and cause pavement and track damage.

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Key “Transportation” Messages from US Global Change Research Program

- Increased intensity of strong hurricanes would lead to more evacuations, infrastructure damage and failure, and transportation interruptions.
- Arctic warming will continue to reduce sea ice, lengthening the ocean transport season, but also resulting in greater coastal erosion due to waves.
- Permafrost thaw in Alaska will damage infrastructure. The ice road season will become shorter.

Regulation -- Proposed CEQ Guidance

"…environmental analysis and documents …should provide … information about….the relationship of climate change effects to a proposed action or alternatives, including the relationship to proposal design, environmental impacts, mitigation and adaptation measures."

Proposed CEQ Guidance

- Agencies should determine which climate change impacts warrant consideration
- Through scoping process, agencies should determine whether climate change considerations warrant emphasis or de-emphasis
- Sensitivity, location, and timeframe of a proposed action determines the degree to which consideration of these predictions or projections is warranted
- Effects may include effects on the environment, on public health and safety, and on vulnerable populations who are more likely to be adversely affected by climate change

Proposed CEQ Guidance

- Observed and projected effects of climate change … are most appropriately described as part of the current and future state of the proposed action's "affected environment."
- Climate change can affect the integrity of a development or structure …. increase the vulnerability of a resource, ecosystem, or human community…. can magnify the damaging strength of certain effects of a proposed action.
- Focus of analysis should be on the aspects of the environment that are affected by the proposed action and the significance of climate change for those aspects of the affected environment.

Proposed CEQ Guidance

- In cases where adaptation to the effects of climate change is important, the significant aspects of these changes should be identified in the agency's final decision and adoption of a monitoring program should be considered. Monitoring strategies should be modified as more information becomes available and best practices and other experiences are shared.

US Army Corps of Engineers

- Required to incorporate sea-level rise projections into “managing, planning, engineering, designing, constructing, operating, and maintaining USACE projects and systems of projects.”
- USACE is starting to raise adaptation concerns for transportation projects through their 404 and bridge permitting authorities (e.g., Bonner Bridge in NC Outer Banks).

III. Some Examples

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Seattle

- Bridges and culverts (increased mean annual rainfall, increased intensity of rainfall events, sea level rise),
- Causeways and coastal roads (sea level rise and increased frequency and intensity of storm surges),
- Pavement surfaces (increased mean annual temperature),
- Surface drainage (increased intensity of rainfall events), and
- Hillside slope stability (increased mean annual rainfall and increased intensity of rainfall events).

(Soo Hoo 2005)

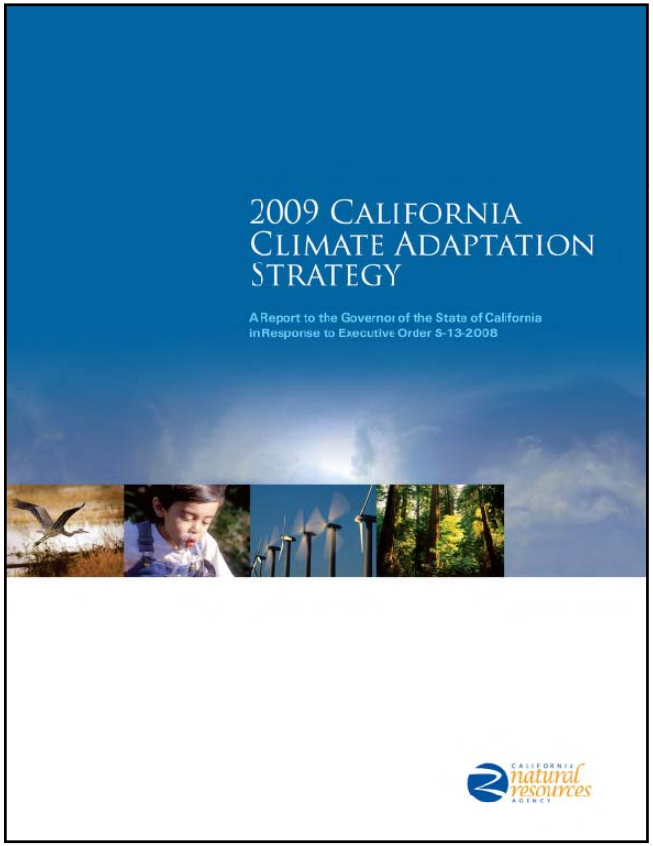
State Initiatives

California Executive Order #S-13-08, Nov. 14, 2008, Directing State Agencies to Plan for Sea Level Rise and Climate Impacts.

Washington State: Responding to Climate Change: E2SHB 1303 directed the Departments of Ecology and Community Trade and Economic Development (now Commerce) to work with the Climate Impacts Group at the University of Washington to assess climate change impacts in the state.

Massachusetts: Global Warming Solutions Act of 2008: Climate Change Adaptation Advisory Committee: Analyze strategies to prepare for the impacts of climate change to the Commonwealth

California



"State agencies should generally not plan, develop, or build any new significant structure in a place where that structure will require significant protection from sea level rise, storm surges, or coastal erosion during the expected life of the structure."

Anticipated Climate Changes

Temperature:
- 2 - 5 °F by 2050
- 4 - 9 °F by 2100

Precipitation:
- 12 - 35% by 2050

Sea Level:
- 12 – 18 inches by 2050
- 21 - 55 inches by 2100

Source: 2009 Scenarios Project

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Transportation Strategies

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Develop a detailed climate vulnerability assessment and adaptation plan for California's transportation infrastructure.

Incorporate climate change vulnerability assessment planning tools, policies, and strategies into existing transportation and investment decisions.

Develop transportation design and engineering standards to minimize climate change risks to vulnerable transportation infrastructure.

Incorporate climate change impact considerations into disaster preparedness planning for all transportation modes.

http://www.climatechange.ca.gov/adaptation/index.html

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Gulf Coast Phase I

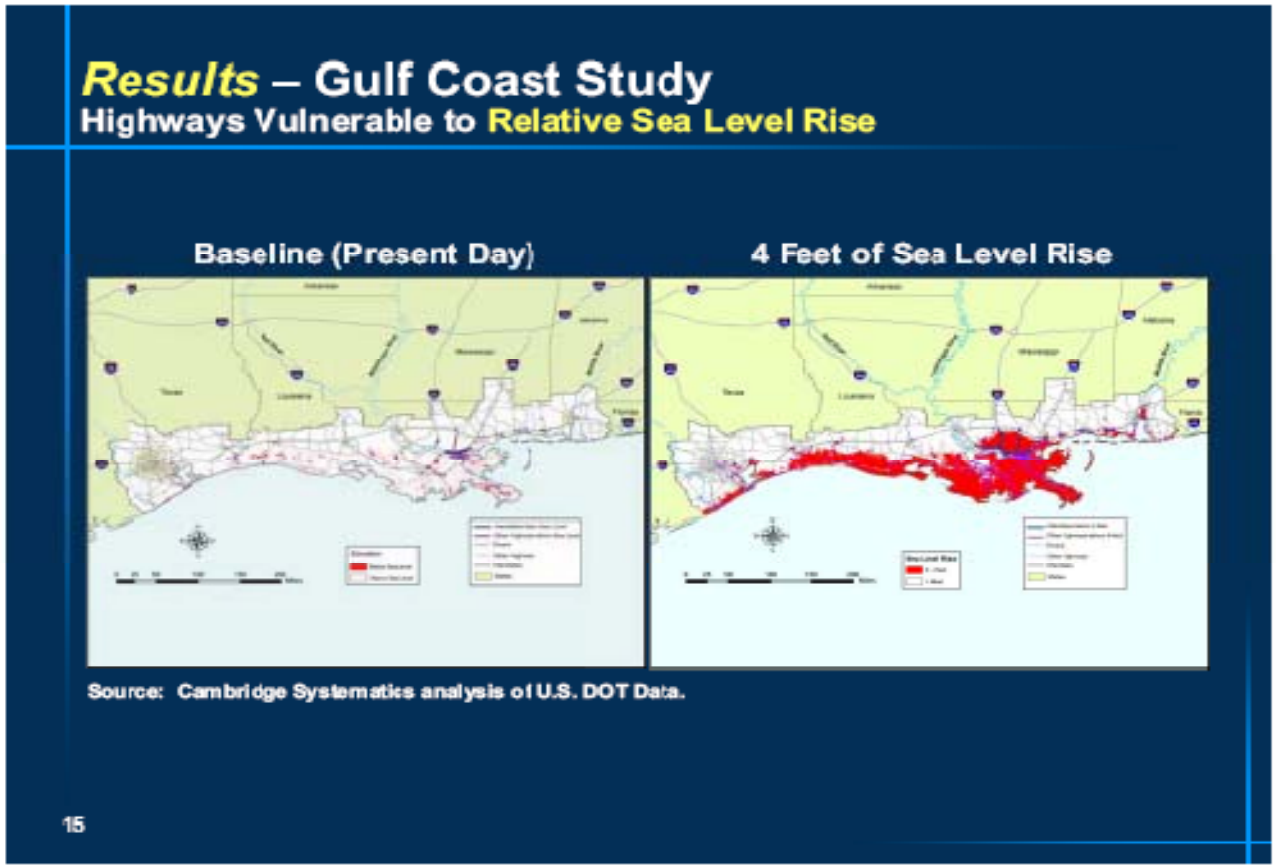
By 2100, temperatures will be approaching those of current design standards…design changes should be accommodated now (for long life infrastructure such as bridges) to ensure that facilities will be able to accommodate higher temperatures in the future.

The impact of sea level rise is significant for some, but not all, parts of the region.

Gulf Coast Phase I – Transportation Planning

- Longevity of infrastructure requires integration in planning
- 20-year time frame for planning not conducive for climate change impacts
- Vulnerability of system as well as individual facilities

Gulf Coast Study on Climate Change – Highways and Relative Sea Level Rise



Source: Mike Savonis, FHWA

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Other Countries

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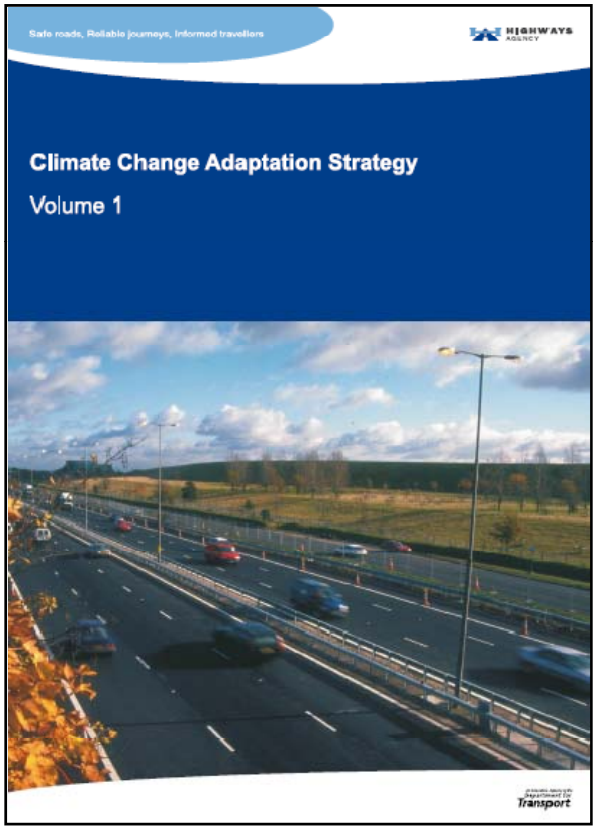
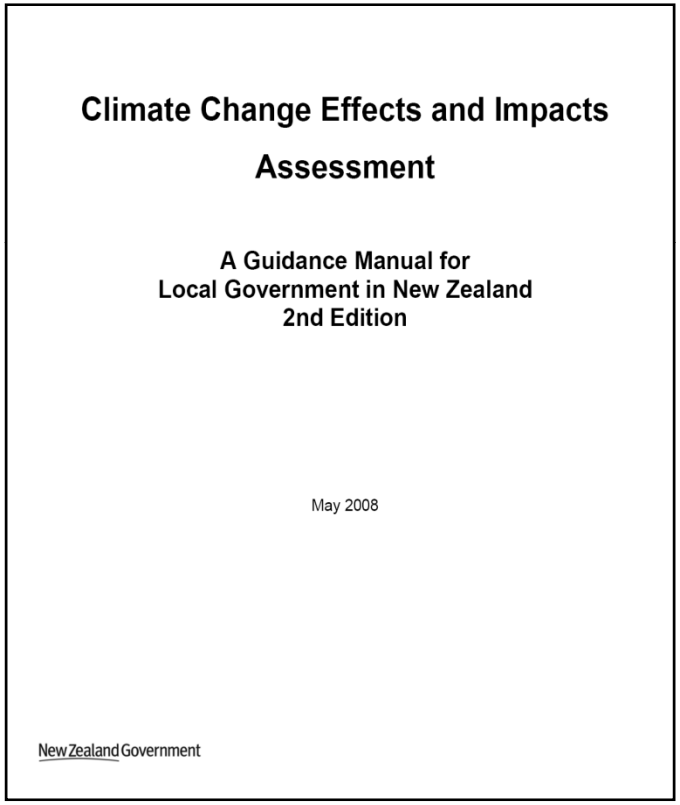


United Kingdom



New Zealand

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UK Highways Agency

Primary Climatic Changes
Increase in average temperatures
Increase in maximum temperatures
Increase in winter rainfall
Reduction in summer rainfall
More extreme rainfall events
Reduction in snowfall
Increased wind speed for worst gales
Sea level rise

UK Highways Agency

Secondary Climatic Change Impacts
Longer growing season
Reduction in soil moisture
Change in groundwater level
Flooding
Reduction in fog days in winter
Reduction in icy days in winter
Frequency of extreme storm surges

Highways Agency High-level Climate-related Risks to Corporate Objectives

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Risk	Examples
Reduced asset condition and safety	Assets deteriorate more quickly due to changes in average climatic conditions, assets are more badly damaged as a result of more extreme climatic events.
Reduced network availability and/or functionality	Need for restrictions on the network to maintain safety, increased need for roadworks
Increased costs to maintain a safe, serviceable network	Construction/maintenance/repairs/renewal required more often; more extensive efforts required; new (more expensive) solutions required
Increased safety risk to road workers	Increased risk to construction and maintenance workers and traffic officers as a result of the need to work on the network more often and during extreme events
Increased program and quality risks due to required changes in construction activities	More onerous design requirements; new technical solutions with higher uncertainty affecting project programs and/or quality
Internal operational procedures not appropriate	Effects of climate change require new ways of working; changed or new business processes/skills/competencies
Increased business management costs	Need for more staff, more frequent (expensive) incidents to pay for; need for more research

New Zealand Transport Agency

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Vulnerable assets…

- Bridges
- Culverts
- Causeways and coastal roads
- Paved surfaces
- Surface drainage
- Hillside slopes

IV. Massachusetts Example

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MassDOT Climate Adaptation Program

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Presented by:

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Massachusetts Department of Transportation

July 2008 Global Warming Solutions Act Signed

GHG Reduction Goals

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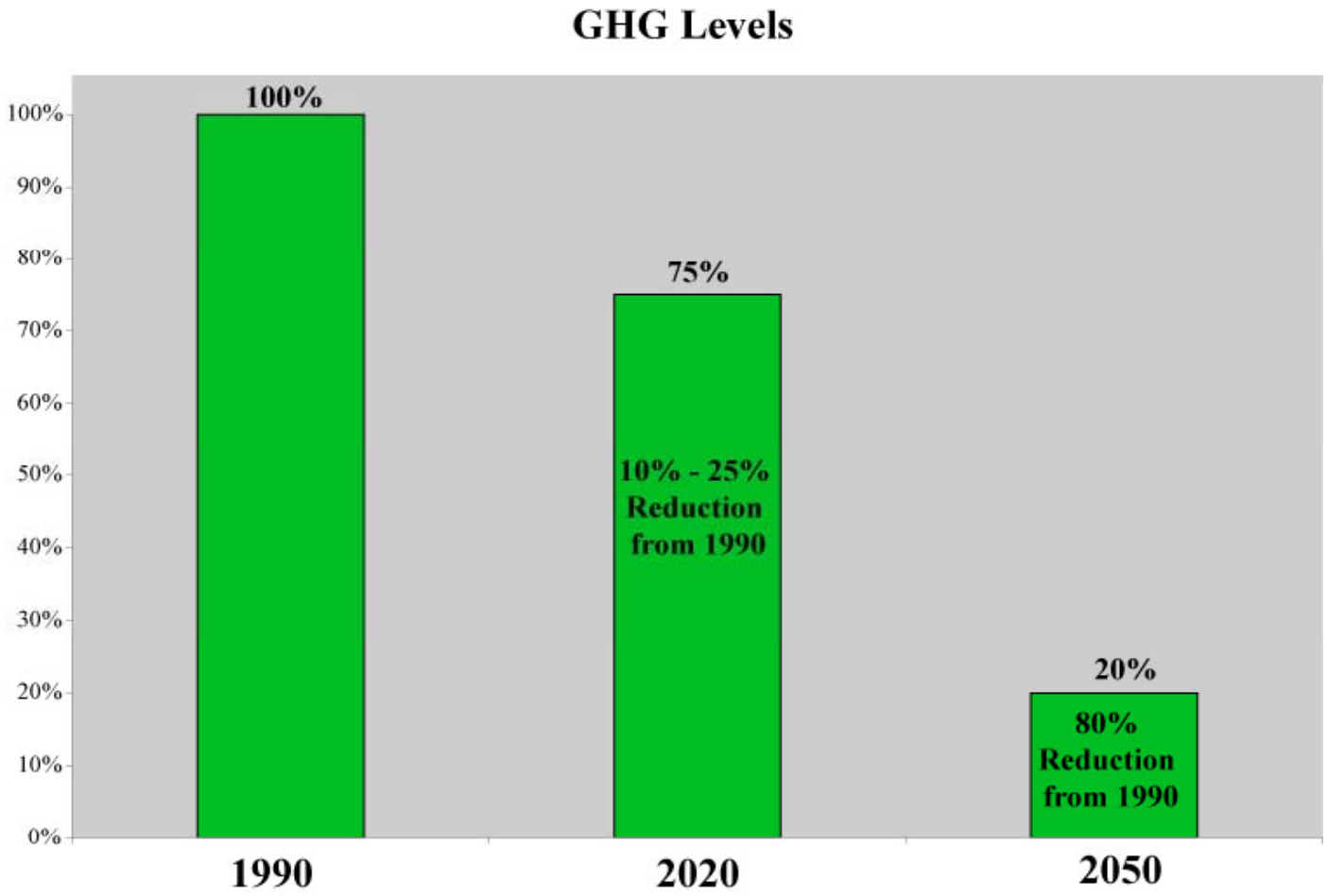

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MAINE
NEW HAMPSHIRE
VERMONT
Connecticut
NEW YORK
APPALACHIAN MTS.
Haverhill
Lowell
Lawrence
Gloucester
Fitchburg
Leominster
Salem
Lynn
Pittsfield
MASSACHUSETTS
Cambridge
Marlborough
BOSTON
Northampton
Quincy
Holyoke
Worcester
BERKSHIRE HILLS
Springfield
Brockton
Cape Cod
Provincetown
Attleboro
Plymouth
Taunton
Cape Cod Bay
CONNECTICUT
RHODE ISLAND
Fall River
Hyannis
New Bedford
Martha's Vineyard
North Atlantic Ocean
Nantucket I.

Coastal Bridges

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AASHTO Committee on Environment and Sustainability

U.S. Department of Transportation Federal Highway Administration

Global Warming Solution Act Adaptation Strategies

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- Natural Resources & Habitat Subcommittee
- Local Economy Subcommittee
- Human Health & Welfare Subcommittee
- **Key Infrastructure Subcommittee**
- Coastal Zone & Ocean Subcommittee

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MassDOT Highway Division Adaptation Ongoing Efforts

- Monitor bridges through the Bridge Inspection program and Scour program to ensure safety and develop measures (armoring) to protect the structure until proposed replacement.

- Projects addressed on a case-by-case basis where flooding issues have been identified.

- Bridge projects with low-chord below 10-year flood are subject to more intense review. Two foot clearance preferred but ROW, Environmental, Cultural impacts must be considered.

Adaptation Recommendations
Mid-Term (2-5 Years) - Coastal Areas

- Mapping – Using Light Detection and Ranging (LIDAR) survey to map coastal assets

- Develop GIS based asset inventory

- Perform Sea Level Rise Vulnerability Assessment
  - Identify & Prioritize Critical Transportation Assets

- Develop design requirements on a project-by-project and priority basis

Adaptation Recommendations
Mid-Term (2-5 Years) – Inland Areas

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- Update Peak Flood Flow Frequency Regional Regression Equations to produce more accurate flood level predictions
  - 40-year old data

- Identify and Prioritize inland vulnerable assets

- Develop design requirements on a project by project basis
  - Increased Clearances
  - Rip-Rap, Scour Protection
  - Relocation – Most Extreme

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MassDOT Long Term Adaptation Recommendations

- Continue development of engineering standards with FHWA and AASHTO
- Progressively adapt standards as:
  - more data becomes available
  - climate change impacts are realized
  - Climate change events are predicted with greater accuracy
  - universal models are developed

Next Steps

- EEA to finalize Adaptation Recommendation Report for MA Legislature
- Work with USGS to start LIDAR Mapping
- Continue to assess on a project-by-project basis and adapt as more information becomes available

Next Steps cont.

- Educate Stakeholders so they understand the consequences of no action.

- Work Closely with Environmental Agencies to develop streamlined permitting to address changing needs

New Commuter Boat?

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V. Climate Adaptation Planning for Transportation

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Adaptation per the IPCC

"... the degree to which adjustments are possible in practices, processes or structures of systems to projected or actual changes of climate. ***Adaptation can be spontaneous or planned,*** *and can be carried out in response to or in anticipation of changes in conditions."*

UK Highways Agency Adaptation Strategy Model

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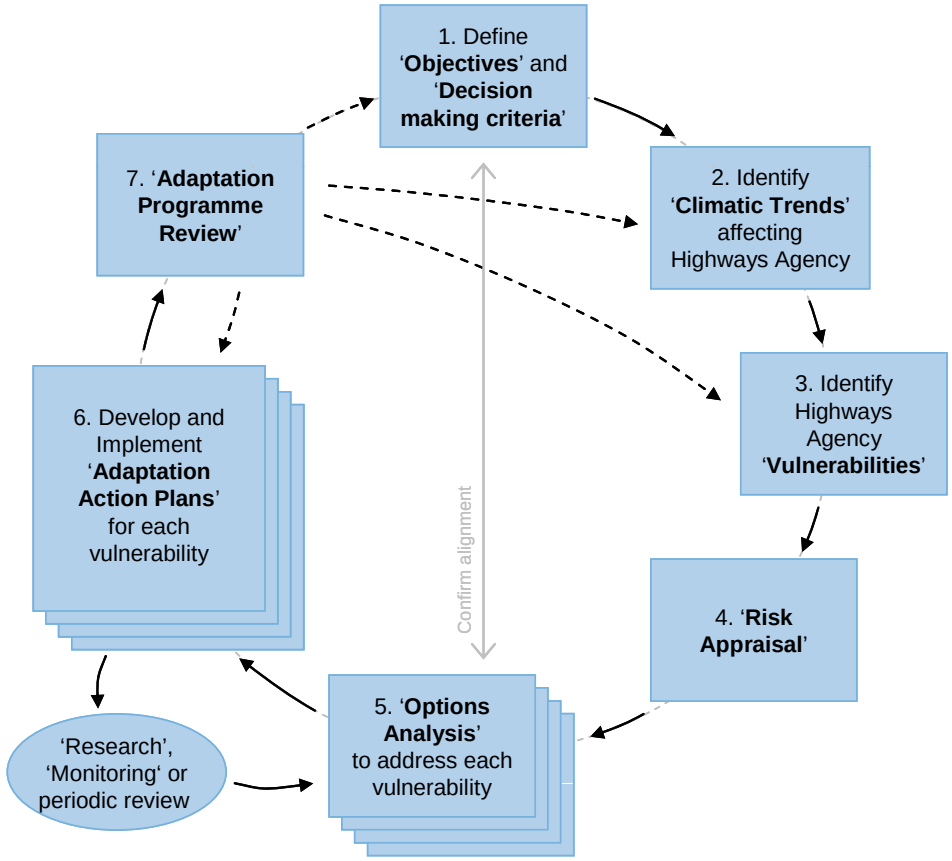
- Model identified potential impacts of climate change of the UK road network
- Resulted in a climate change adaptation strategy
- Strategy addresses design, construction, and maintenance
- Includes a risk appraisal for all operations



Climate Adaptation Planning

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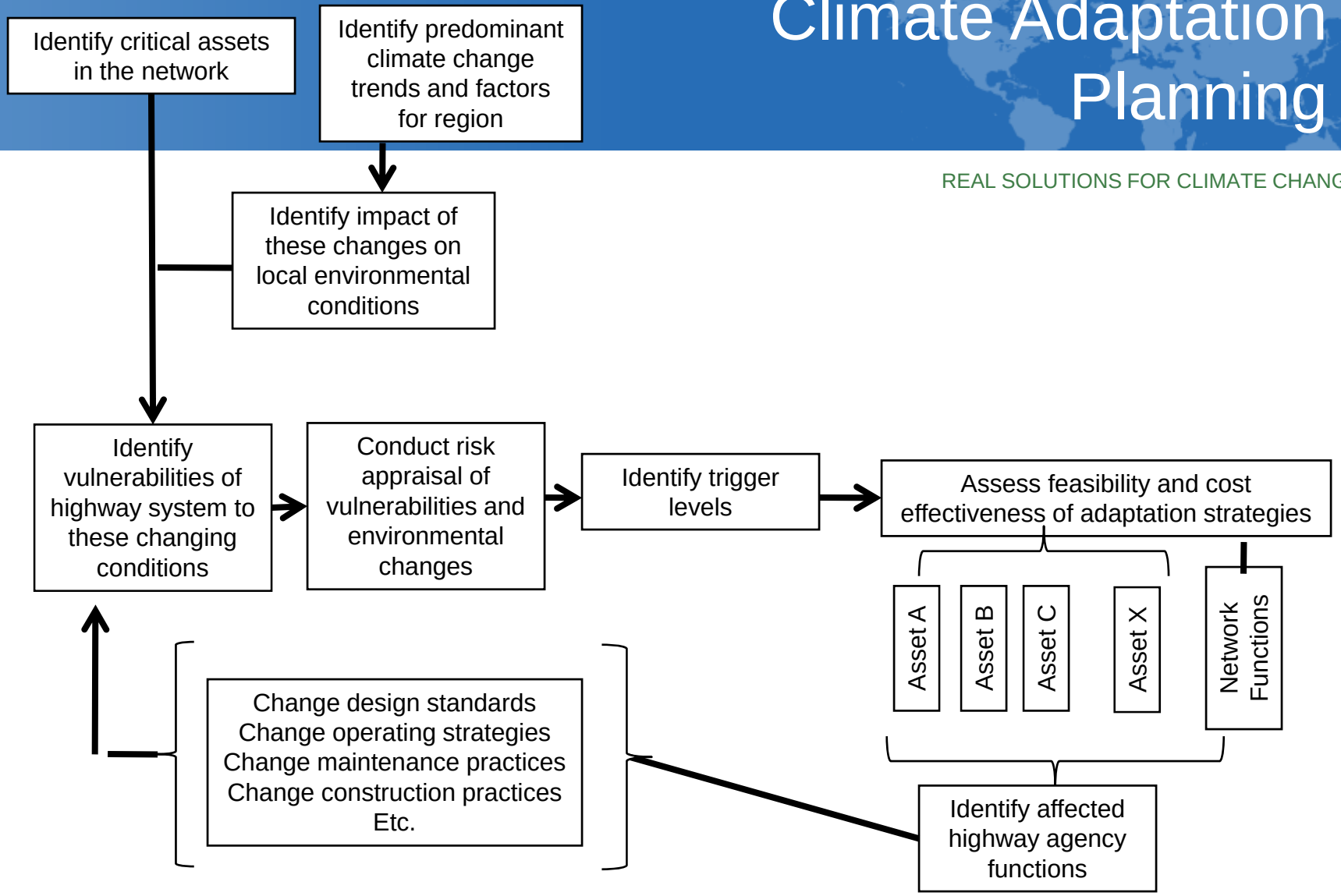
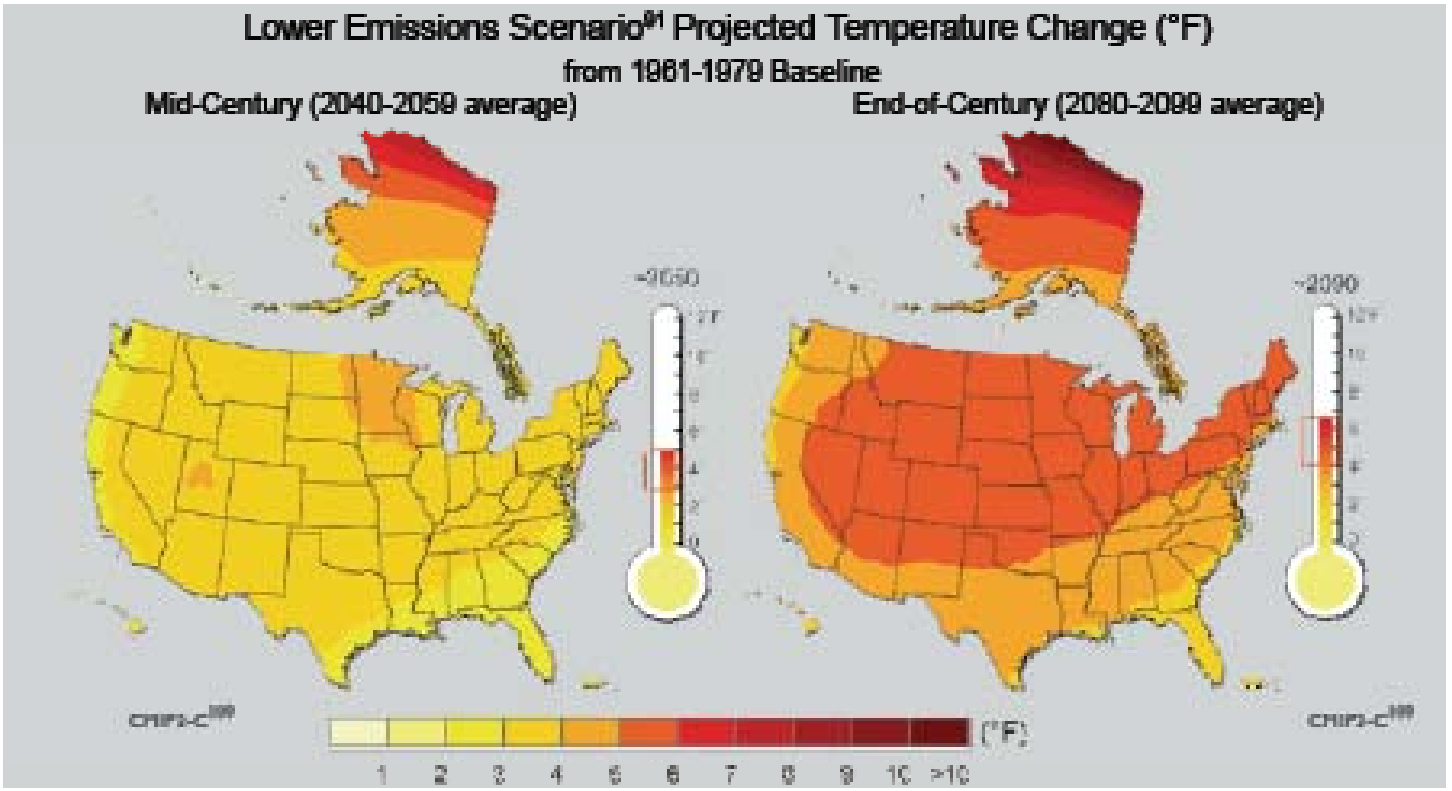


Understanding Possible Climate Changes

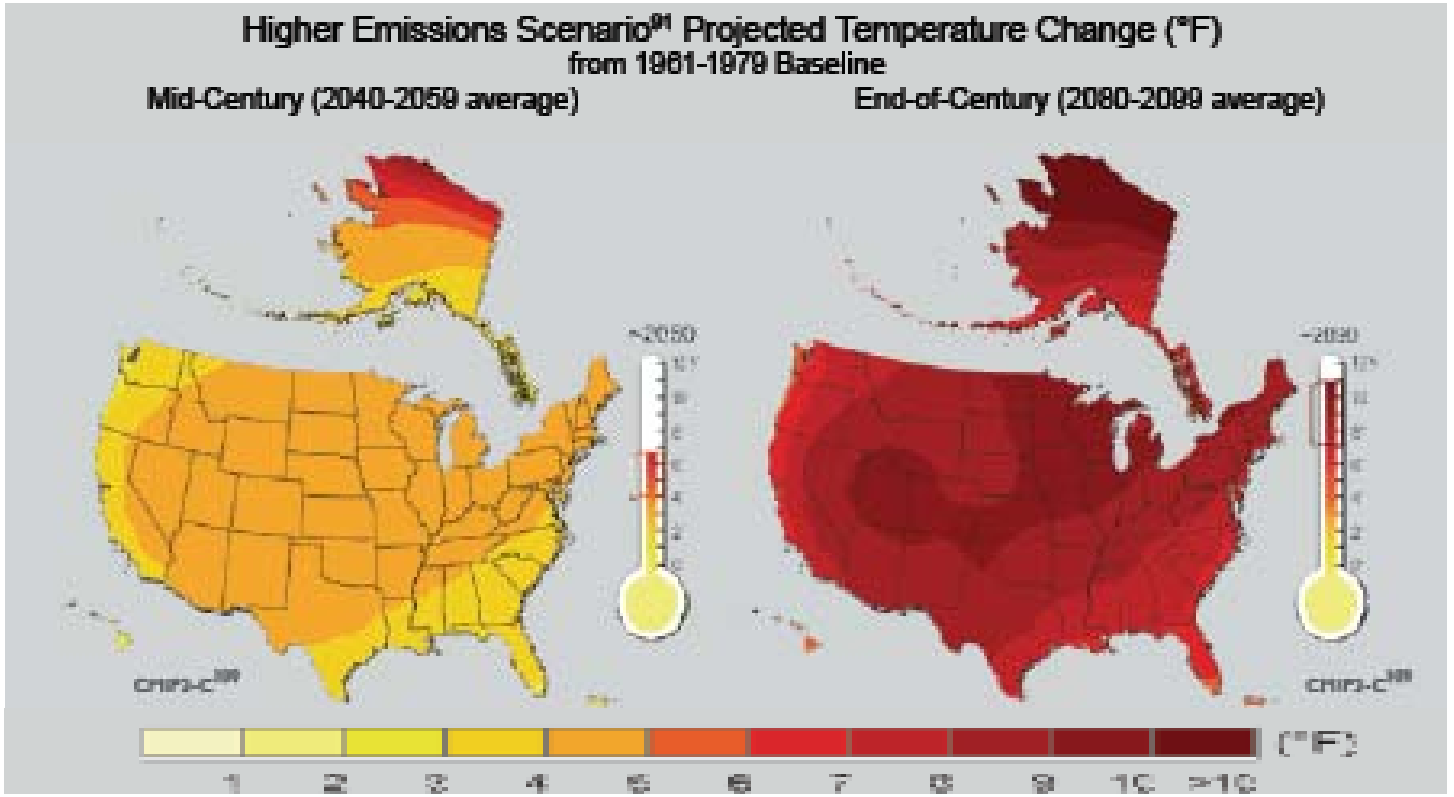
Low Scenario: Up to 6.5 degree rise by 2090



Source: Global Climate Change Research Program, 2009

Understanding Possible Climate Changes

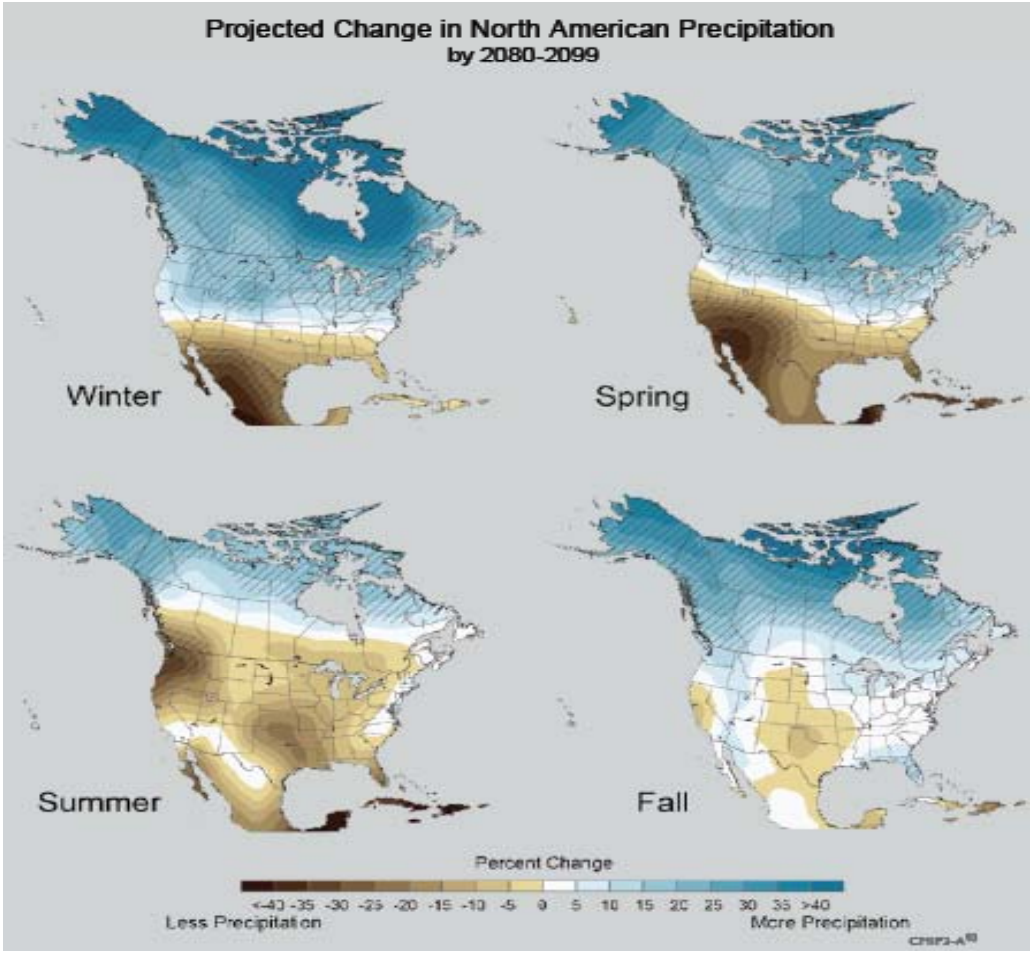
High Scenario: Up to 11 degree rise by 2090



Source: Global Climate Change Research Program, 2009

Understanding Possible Climate Changes

Possible Change in Precipitation—2080-2099



Source: Global Climate Change Research Program, 2009

Understanding Possible Climate Changes

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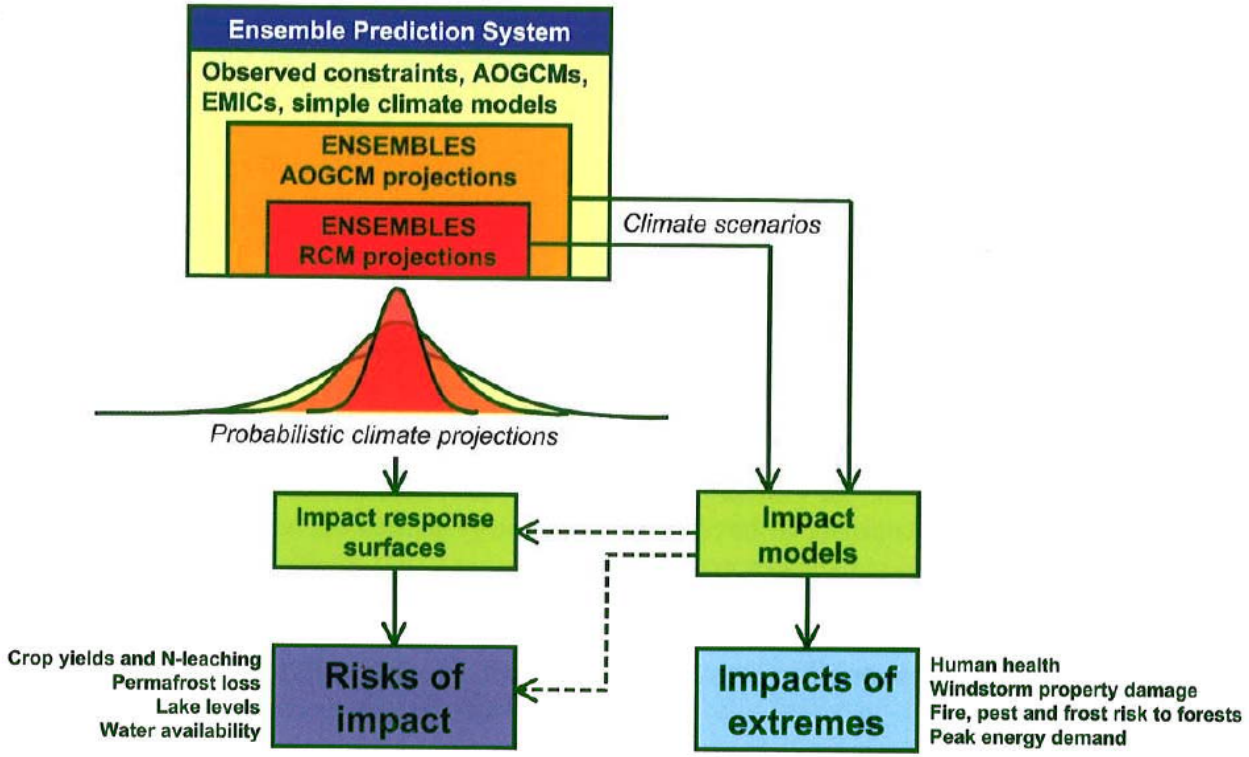
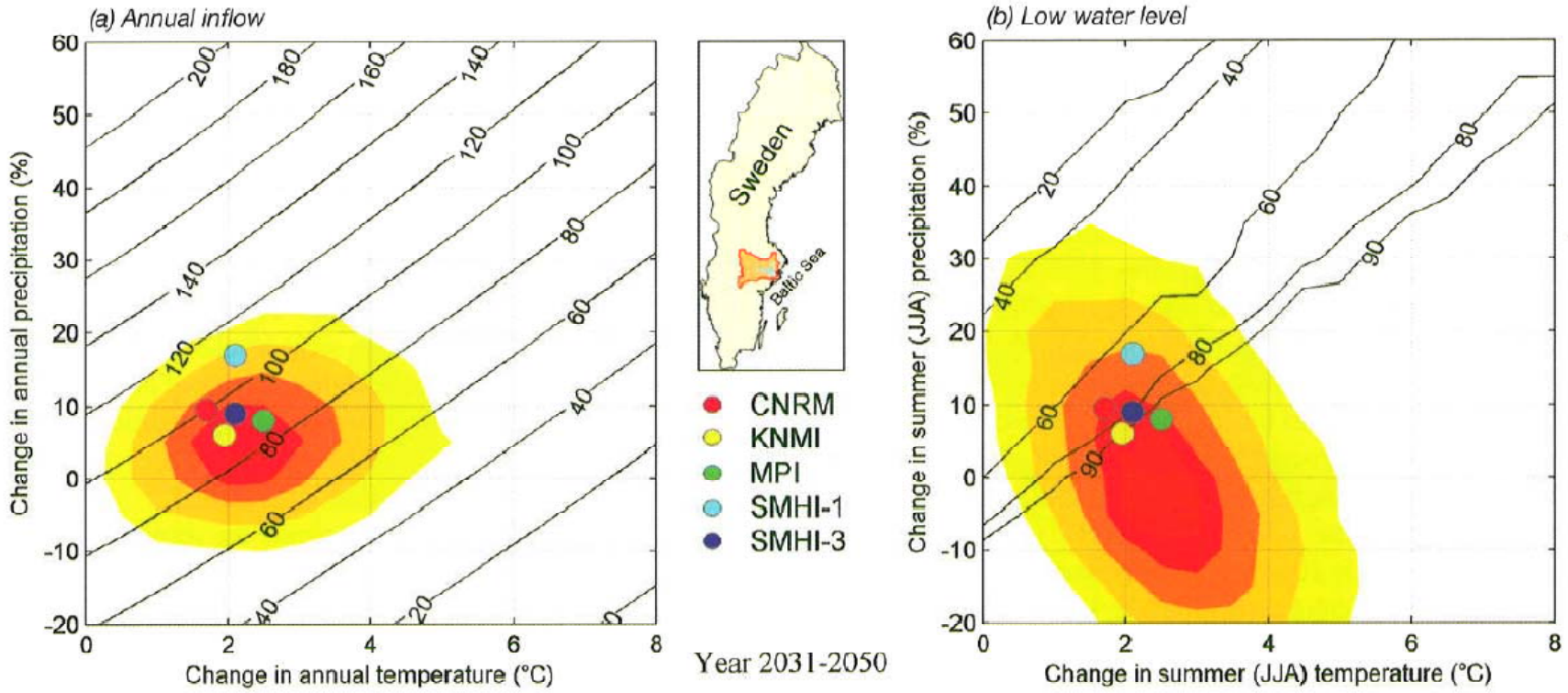
Probabilistic and Impact Models Approaches



Ensembles, November 2009. *Climate Change and Its Impacts at Seasonal, Decadal and Centennial Timescales*,, Met Office Hadley Centre, Exeter, UK.

Probability of Occurrence



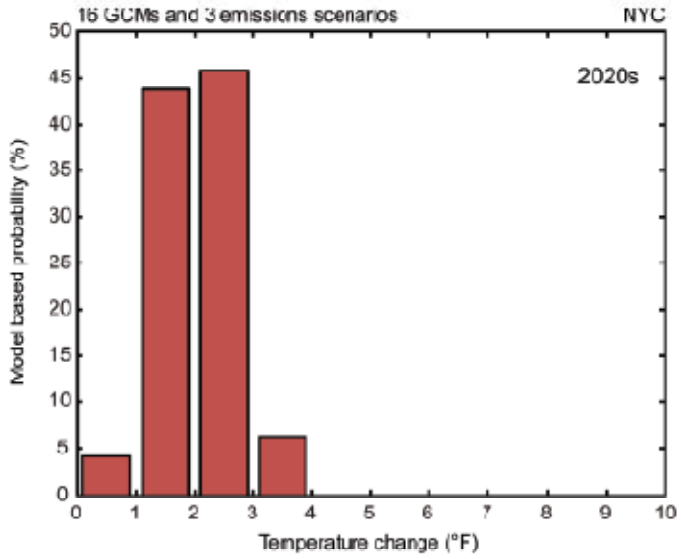
Ensembles, November 2009. *Climate Change and Its Impacts at Seasonal, Decadal and Centennial Timescales*,, Met Office Hadley Centre, Exeter, UK.

Frequency Distributions

FIGURE 10.

Model-Based Frequency Distribution of Temperature Changes

Frequency distribution of model-based temperature changes (°F) in NYC, relative to the 1971-2000 base period, for 16 models and three emissions scenarios



Risk Rating: Victoria

Table 9: Risk Rating Matrix

Likelihood	Consequences				
	Insignificant 1	Minor 2	Moderate 3	Major 4	Catastrophic 5
A (almost certain)	L	M	H	E	E
B (likely)	L	M	M	H	E
C (moderate)	L	L	M	H	E
D (unlikely)	L	L	M	M	H
E (very unlikely)	L	L	L	M	M

E - Extreme risk, requiring immediate action.
H - High risk issue requiring detailed research and planning at senior management level.
M - Moderate risk issue requiring change to design standards and maintenance of assets.
L - Low risk issue requiring action through routine maintenance of assets.

Holper, Paul, Sean Lucy, Michael Nolan, Claudio Senese, and Kevin Hennessy (eds.), 2006: *Infrastructure and Climate Change Risk Assessment for Victoria*. Victoria Government. (http://www.greenhouse.vic.gov.au/CA256F310024B628/0/2021C307264A6473CA2572DD00055CBB/$File/Climate+change+and+Infrastructure+Final.pdf)

Proactive Strategies to Flood Risk

- Preventing flooding by improving the rainfall capture and storage capacity of a catchment (e.g. by enhancing or mimicking the water storage capacity of the soil);
- Increasing conveyance capacity to disperse floodwaters;
- Creating policies to maintain existing levels of service which incorporate climate change factors at the time of repairs or upgrades;

NZ Transport Agency, Climate Change Effects on the Land Transport Network, Volume Two: Approach to Risk Management, 2009

Proactive Strategies to Flood Risk, cont'd

- Establishing physical protection measures, e.g. building stop-banks;
- Managing the effects of flooding by removing at-risk land use such as infrastructure and the built environment in floodplains; and
- Managing the expectations of communities in flood-prone areas to expect and cope with flood events.

NZ Transport Agency, Climate Change Effects on the Land Transport Network, Volume Two: Approach to Risk Management, 2009

Projects to Watch Out For

- Gulf Coast II
- NCHRP 20-83(5) – Climate Change and the Highway System: Impacts and Adaptation Approaches

IV. Adaptation at FHWA

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Adaptation at FHWA

An overview of FHWA initiatives to develop information, tools, and procedures necessary to support the consideration of the impacts of climate change.

MARCH 31, 2010

Presented by:

APRIL MARCHESE
Director, FHWA Office of Natural & Human Environment

A Risk to the Nation's Multi-Modal Transportation System

- Risk to efficient operations as well as to physical infrastructure
- Risk to inland states as well as to coastal states
- Affecting freight as well as passenger travel
- Disrupting seaports, airports, railroads, transit, and highway travel – and their interconnections
- May increase weather-related traffic incidents

FHWA Adaptation Strategy - *Forthcoming*

- Foundation and Plan for Climate Change Adaptation Activities
- Multidisciplinary Effort
  - Office of Planning, Environment & Realty
  - Office of Infrastructure
  - Office of Operations
  - Office of Safety
  - Office of Federal Lands Highway

Vulnerability/Risk Assessment Conceptual Model

- For Assessments of Transportation Systems and Infrastructure
  - Develop inventory of infrastructure assets
  - Gather climate data
  - Assess risk and vulnerability
- Use by State DOTs and MPOs to identify which assets:
  - Are most exposed to threats from climate change
  - Could have the most serious consequences
- Pilots – call for nominations

Regional Climate Change Effects:
Useful Information for Transportation Agencies - *Draft*

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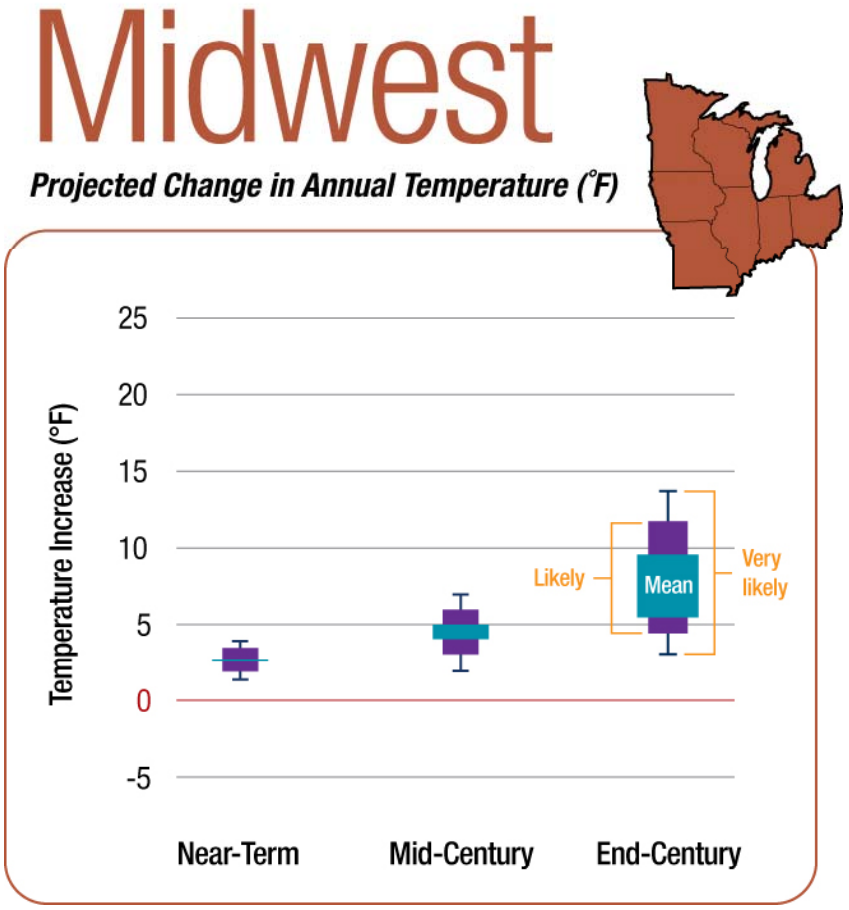
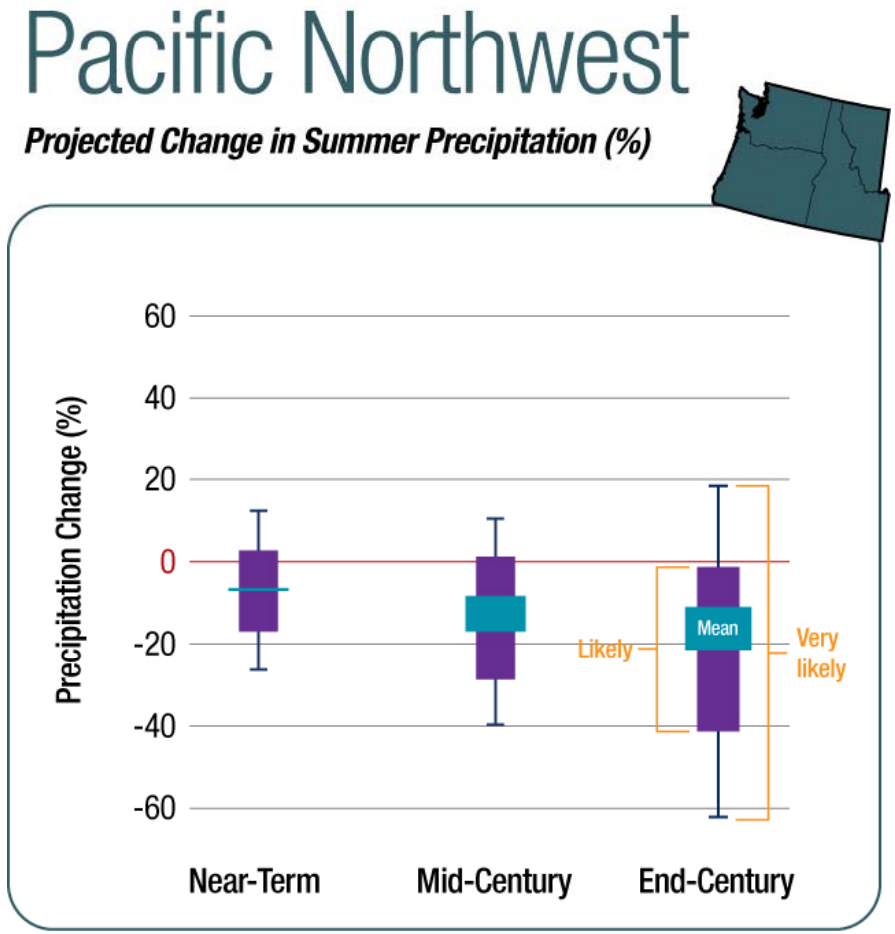
- Baseline information on climate projections for transportation decision makers
- Summarizes current science
- Short, medium and long term
- Low and high GHG emission scenarios
- Assistance from Climate experts -- NOAA, USGS, DOE



Regional Climate Change Effects Report (*draft* results) continued

- 9 US regions: 6 continental, Alaska, Hawaii, Caribbean
- Projected changes by region:
  - Annual and seasonal Temperature
  - Seasonal Precipitation
  - Where data exists:
    - Sea level rise
    - Storm activity



Gulf Coast Study

Impacts of Climate Change and Variability on Transportation Systems and Infrastructure

- Comprehensive assessment of how climate change will affect transportation in the Gulf Coast area
- Phase I
  - Overview of climate change impacts on transportation infrastructure, and general options for addressing these challenges
  - Mobile to Houston, completed 2008

Gulf Coast Study (cont.)

- Phase II
  - Process for assessing critical transportation infrastructure, projecting climate change effects, evaluating vulnerability, and conducting detailed engineering assessments for vulnerable assets in Mobile.

  - Lessons learned and replicable processes that could inform similar analyses in other MPOs
  - Transferrable tools and resources to assist MPOs nationwide
  - Timeframe: 2010-2012

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VII. Information Resources

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Resources -- Websites

- AASHTO: http://www.transportation1.org/RealSolutions/
- Intergovernmental Panel on Climate Change (IPCC): http://www.ipcc.ch/
- US DOT Transportation and Climate Change Clearinghouse: http://climate.dot.gov/index.html
- FHWA Climate Change Program: http://www.fhwa.dot.gov/environment/global.htm
- The Pew Center on Global Climate Change: http://www.pewclimate.org/
- EPA Climate Change Program: http://www.epa.gov/climatechange/
- TRB Climate Change Activities: http://tris.trb.org/climatechange/

Resources – Key Documents

REAL SOLUTIONS FOR CLIMATE CHANGE

- AASHTO, "Primer on Transportation and Climate Change," 2008
- *The Potential Impacts of Climate Change on U.S. Transportation,* Transportation Research Board Special Report 290 (2008).
  Full Report: http://www.trb.org/news/blurb_detail.asp?ID=8794
  Summary: http://onlinepubs.trb.org/onlinepubs/sr/sr290summary.pdf
- *Design Standards for U.S. Transportation Infrastructure: The Implications of Climate Change,* Michael D. Meyer, Georgia Institute of Technology (2008).
  Paper: http://onlinepubs.trb.org/onlinepubs/sr/sr290Meyer.pdf
- *Integrating Climate Change into the Transportation Planning Process,* Federal Highway Administration (2008).
  http://www.fhwa.dot.gov/hep/climatechange/index.htm

Resources – Key Documents

- *Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: Gulf Coast Study, Phase I*, US Department of Transportation Center for Climate Change and Environmental Forecasting (2008)

  Executive Summary: http://www.climatescience.gov/Library/sap/sap4-7/final-report/sap4-7-final-exec-sum.pdf

  Full final report: http://www.climatescience.gov/Library/sap/sap4-7/final-report/

- *Adaptation Fact Sheet,* Pew Center on Global Climate Change
  http://www.pewclimate.org/global-warming-basics/climate_change_101

- *Global Climate Change Impacts in the United States,*
  http://www.globalchange.gov/publications/reports/scientific-assessments/us-impacts

For copies of these slides and webinar recording, go to AASHTO's website:
http://environment.transportation.org/center/products_programs/climate_change_webinars.aspx

For more information on climate change, go to AASHTO's website:
http://realsolutions.transportation.org/Pages/default.aspx

Thank you!