Impacts of Climate Change on Transportation Infrastructure

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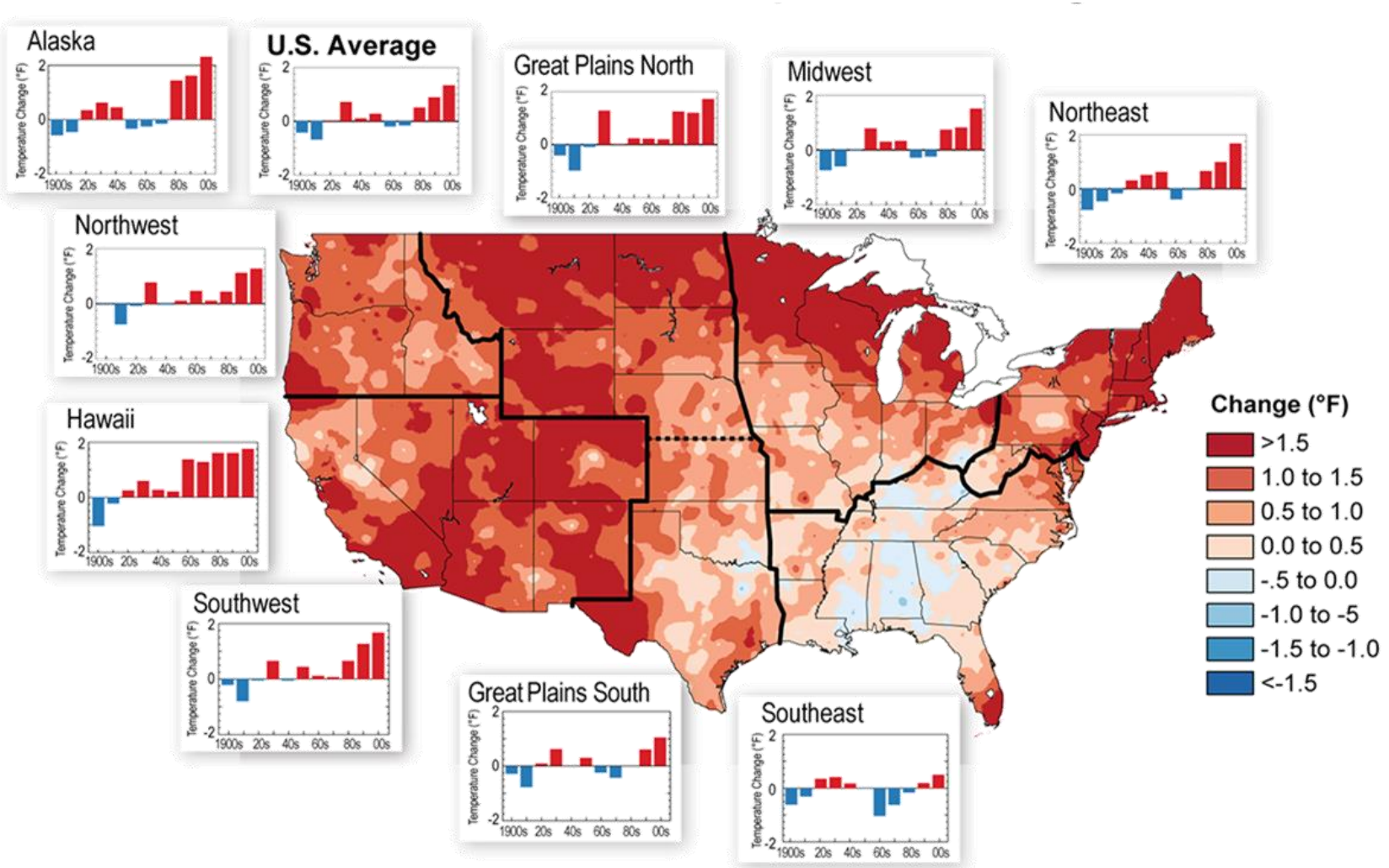
Outline

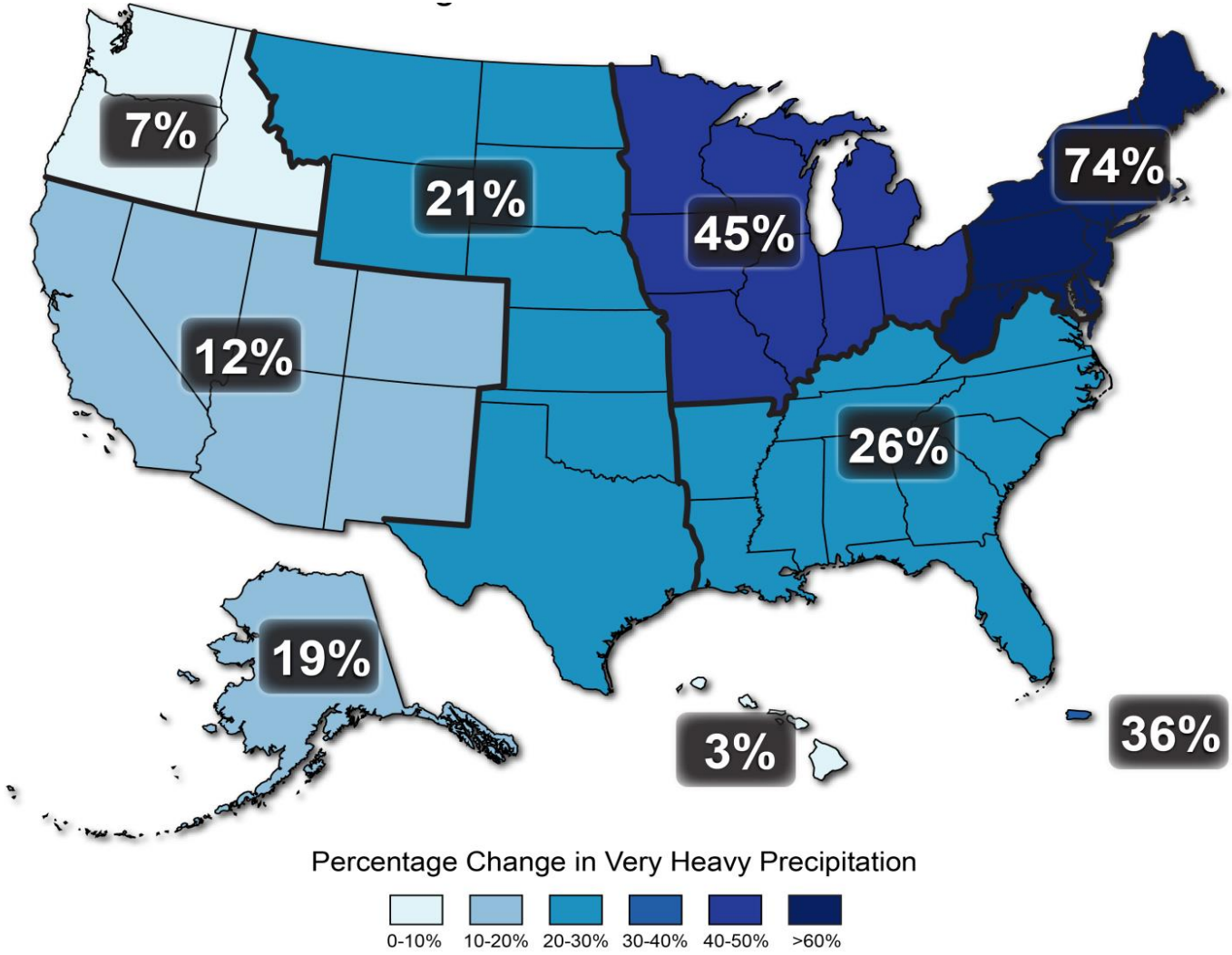
- Background: Intersection of Weather and Infrastructure
- Current Challenges to Engineering for the Future Climate
- Climate Projections
- Innovation and Paths Forward

The U.S. is getting warmer



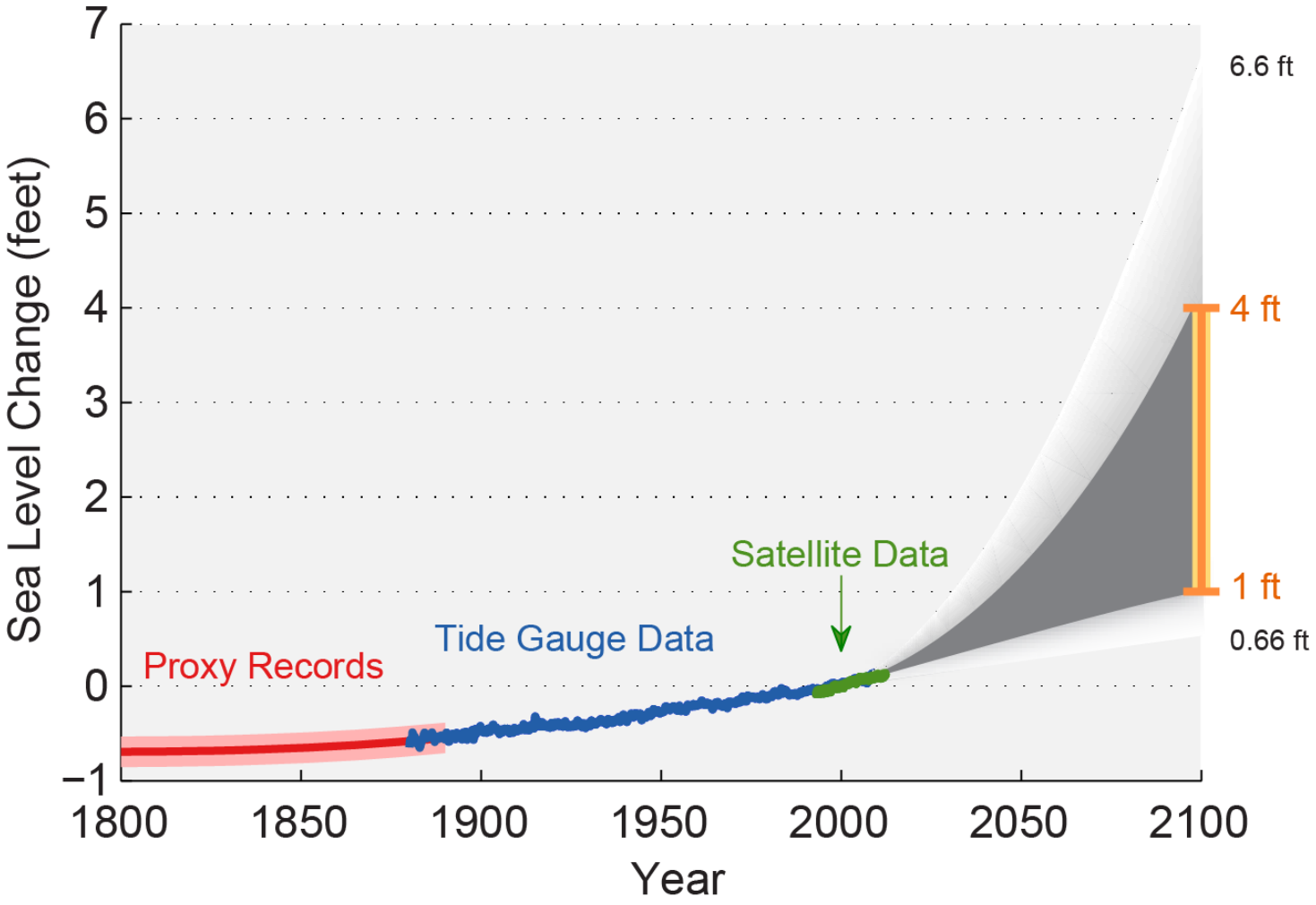
Source: 2014 U.S. National Climate Assessment

Heavy precipitation becoming more frequent



Source: 2014 U.S. National Climate Assessment

Sea level is rising



Source: 2014 U.S. National Climate Assessment

What are the implications to future infrastructure vulnerabilities?

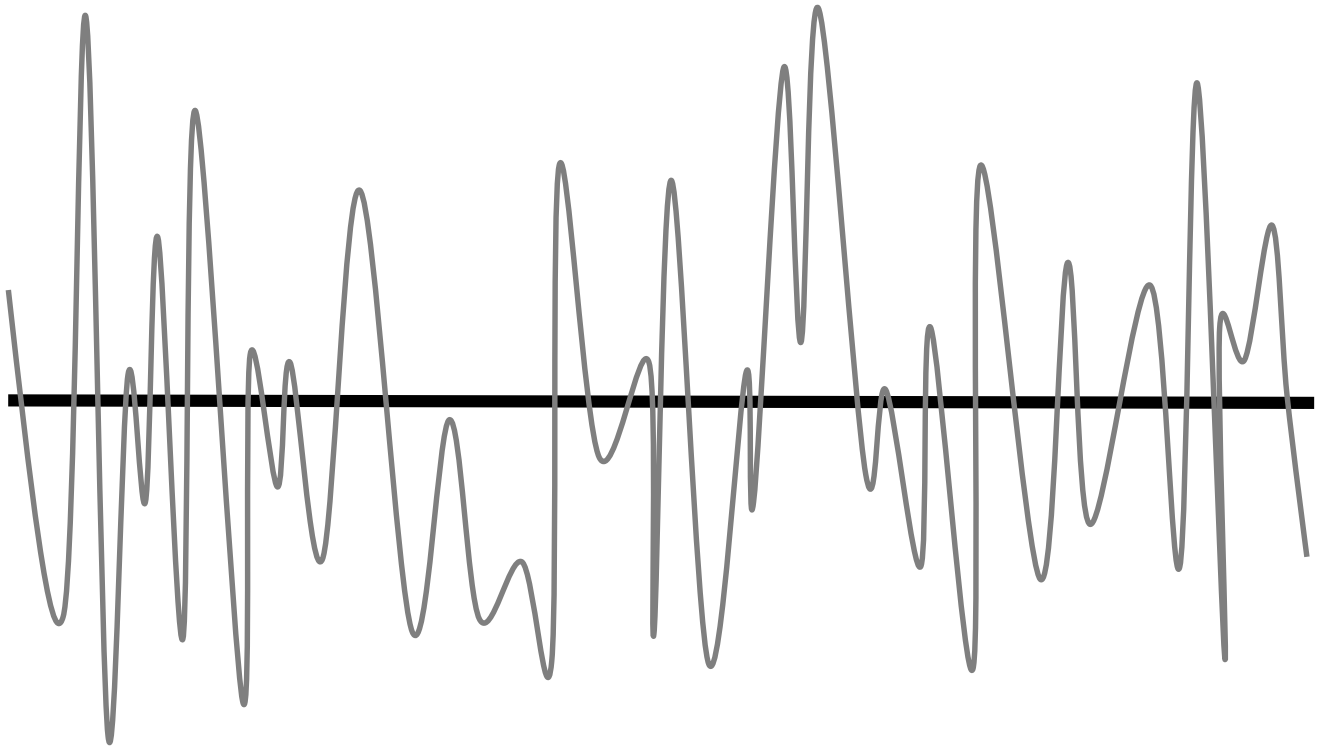
- Damage to infrastructure and property
  - Heat, wind, flooding and wave damage
- Increased O&M costs
- Increased risk of component AND transportation system failure

Climate Change Is Not Being Systematically Incorporated in Infrastructure Engineering

- attention and resources are focused on shorter-term competing priorities;
- challenges identifying and obtaining available climate change information best suited for projects;
- not knowing how to access local assistance; or
- available climate change information does not fit neatly into infrastructure planning processes.

GAO, 2013
www.gao.gov/products/GAO-13-242

In design and planning, we assume long term climate will remain stable and can be predicted based on past **climate normals**



In reality, climate is **non-stationary**: future climate conditions and weather risks will differ from those experienced in the past

How do we incorporate these trends into planning for operations, maintenance, and design of transportation infrastructure?

What Enables Change?
Availability of Climate Info

- Stakeholders are uncertain about where to go and what information to use
- It is a struggle to determine which information is relevant
- End user has to assess which information is high quality

"Loading dock" repository of climate science papers

Need local experts to serve as climate information translators to bridge the gap

The Infrastructure and Climate Network (ICNet)

A collaborative network of over 75 climate scientists and transportation engineers in the Northeast

Accelerating new research & adaptation in climate change impacts to transportation infrastructure

ICNet
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Climate scientists have a good idea of how certain types of extremes are being affected

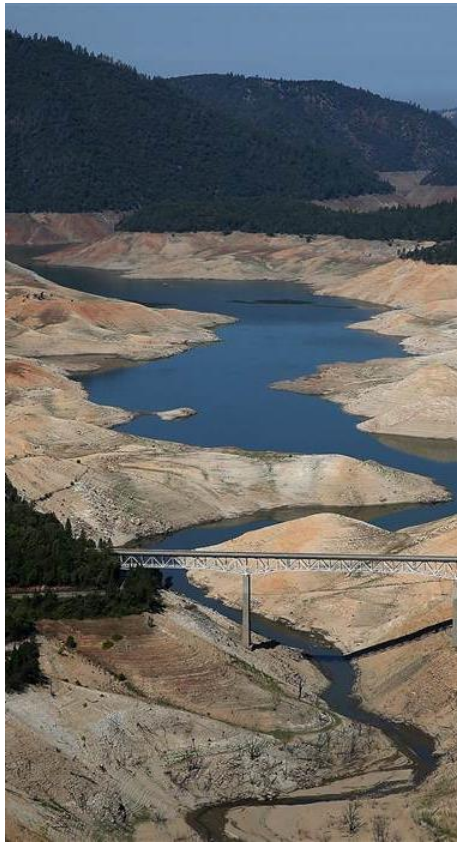
Stronger and more frequent heat waves

Stronger rainfall and winter storms

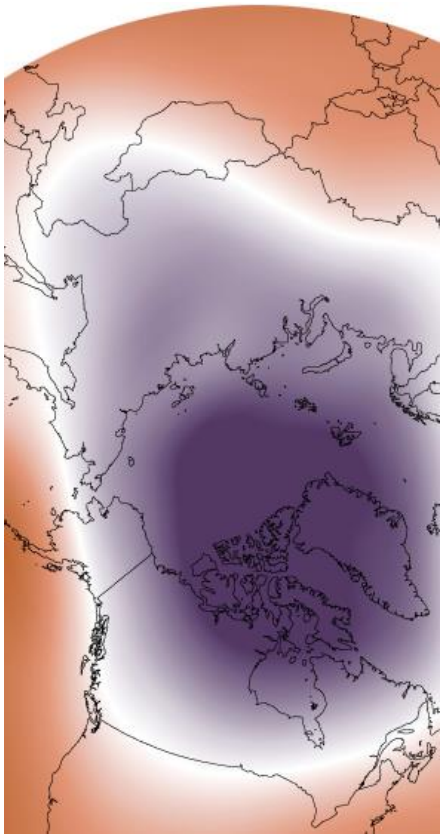
Rising sea level and stronger hurricanes

Larger wildfires in the West

Others, they're still arguing about



Droughts: stronger, but more or less frequent?



Polar Vortex: related to Arctic warming?

Derechos: Hard enough to predict, let alone project!

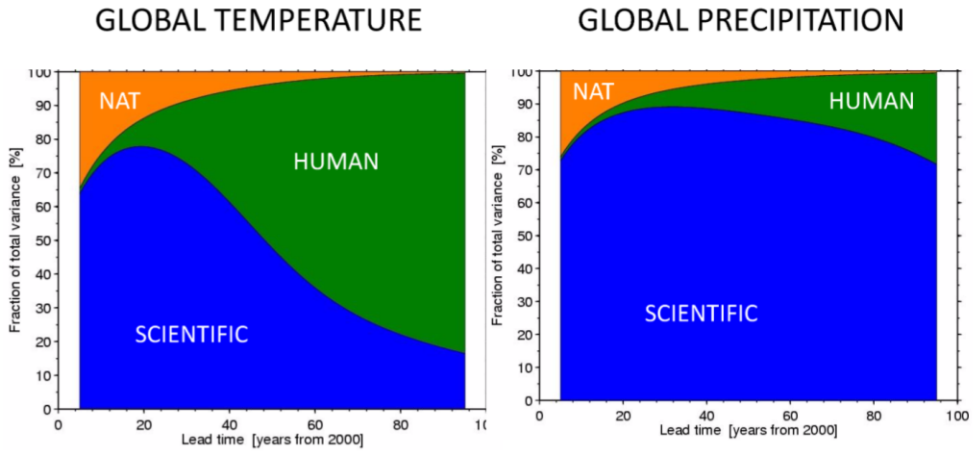
Tornadoes: are they affected?

Engineering Practice Needs a “Best Available Data” Approach

Name

- Armstrong_etal-2014-Flood_Trends_in_Northeast.pdf
- Bales-2014-Climate_Change_n_Floods.pdf
- Hodgkins-Climate-Peak_Flows-sir2010-5094.pdf
- LinsCohn-2011-Stationarity_Wanted_Dead_or_Alive.pdf
- Obeysekera_Salas-2014-Uncert_in_Design_Floods_Under_Non-Stationarity.pdf
- Salas_Obeysekera-2014-Return_Pd_and_Risk-Nonstationary.pdf
- Salvadori-2013-NON-STATIONARITY IN ANNUAL MAXIMUM FLOOD SERIES.pdf
- Serinaldi-2015-Staionarity_is_Undead.pdf
- Tim_Cohn_Flood_Frequency_Analysis.pdf
- Villarini_et_al-2010-Flood_Peak_Distn_Eastern_US.pdf
- Villarini-2009-Stationarity_of_US_Flood_Peaks.pdf
- Villarini-Stationarity_of_Flood_Peaks.pdf
- Walter-2010-Trends_in_Peak_Flows.pdf

The importance of each different source of uncertainty varies in time



Hawkins & Sutton 2009, 2011

WHAT CAN WE DO?

For some purposes, we can

stop right here.

We know enough about the vulnerability of our system and the direction of future change to build resilience into future planning.

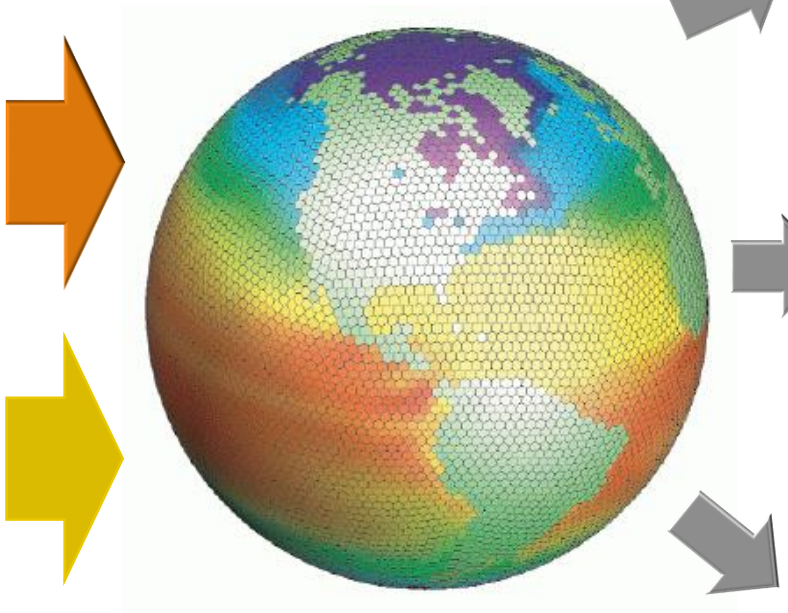
For other planning and design purposes,

we need more.

How do we incorporate climate projections into future planning and design?

1. Identify the climate or weather-related concerns already known to potentially affect the infrastructure that is being designed, built, and/or maintained.
2. Quantify the type of the information required by engineers and transportation experts to assess future impacts and minimize vulnerability
3. Determine which of these risks have changed historically or are likely to change in the future, and the extent to which climate science can provide robust information on these risks to be used in future planning.

For many impacts, climate scientists can develop quantitative projections



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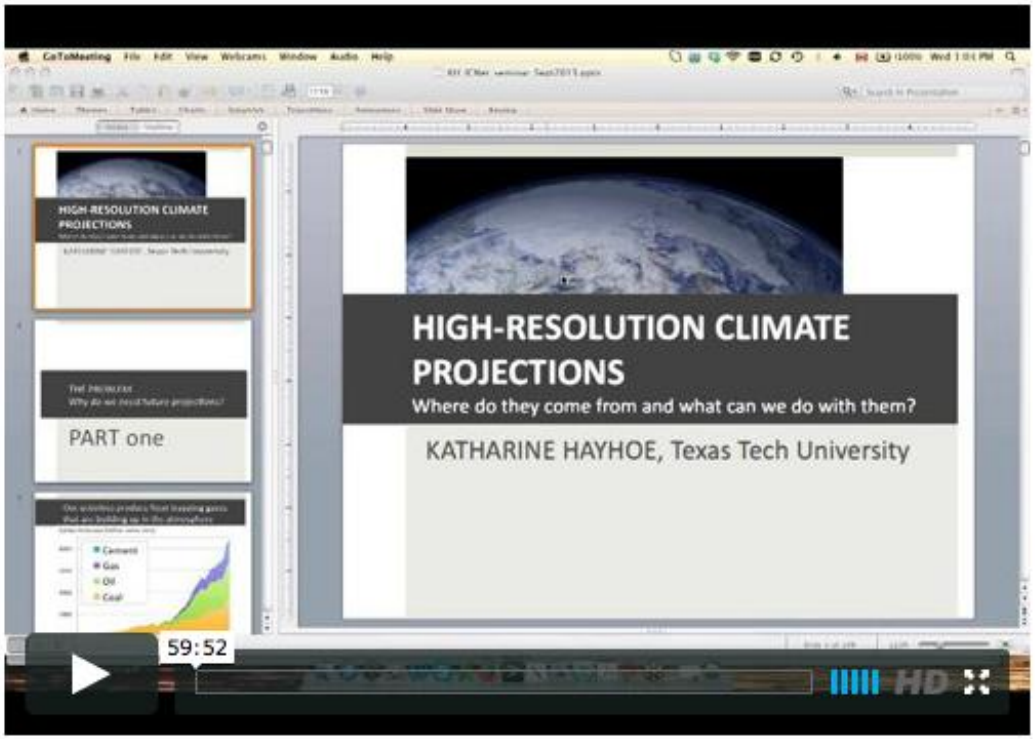
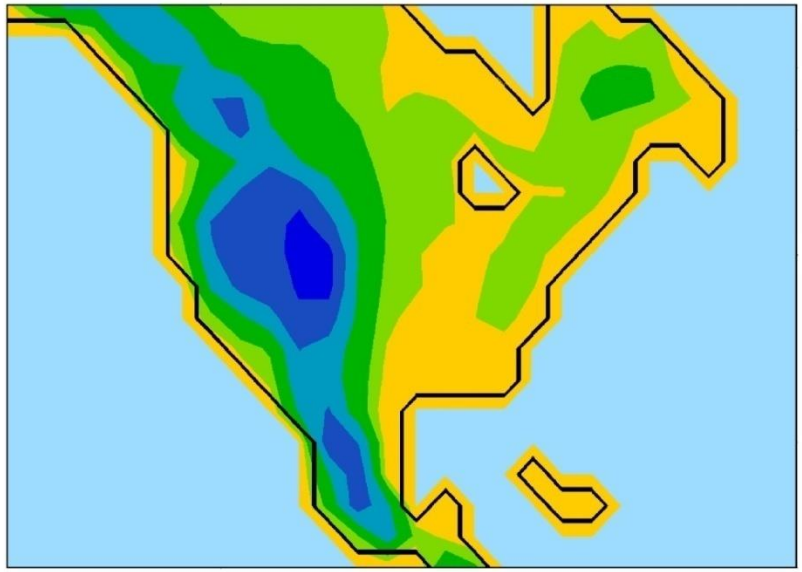
High-resolution climate projections: Where do they come from and what can we do with them?



STEP ONE: Use Climate Model Data from Atmosphere-Ocean General Circulation Models (GCMs)

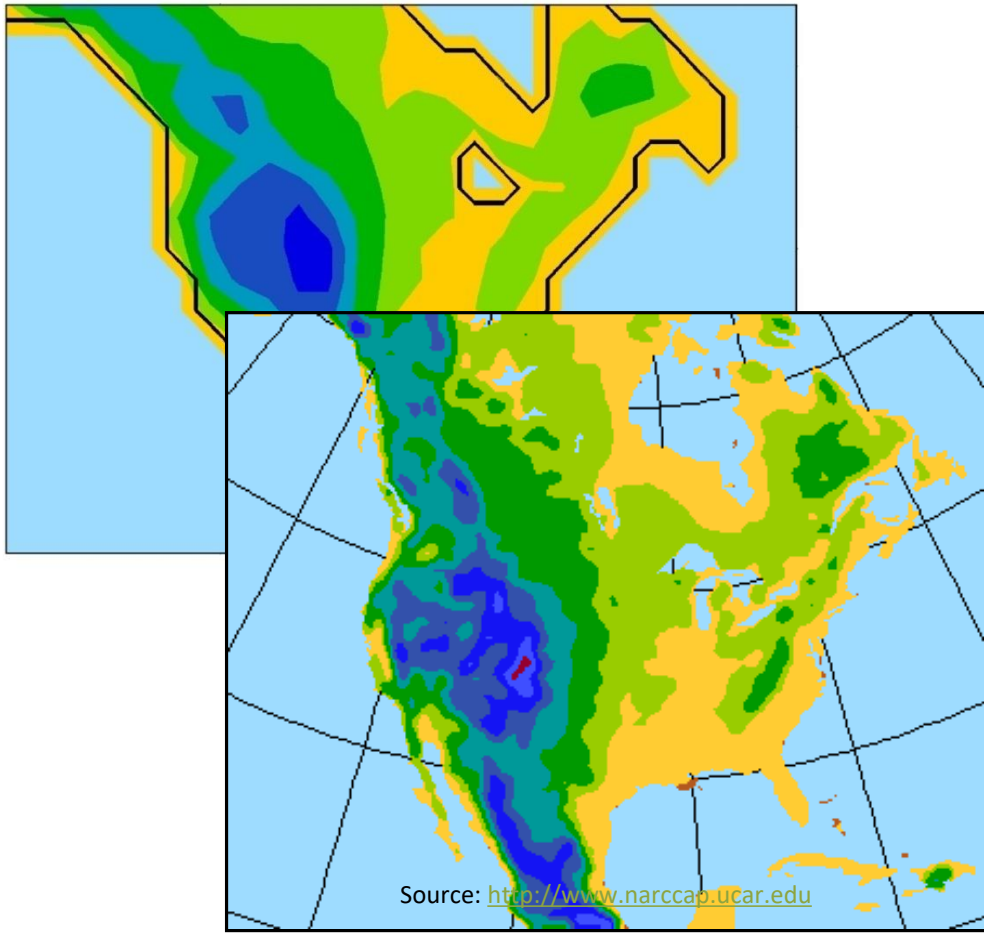
- Spatial Resolution
  - ~ 250 x 250 km pixels
  - Global
- Temporal Resolution
  - 30 to 100 Year Records
  - Daily, Weekly, Monthly
- Output
  - precipitation, temperature, pressure, cloud cover, humidity, etc.



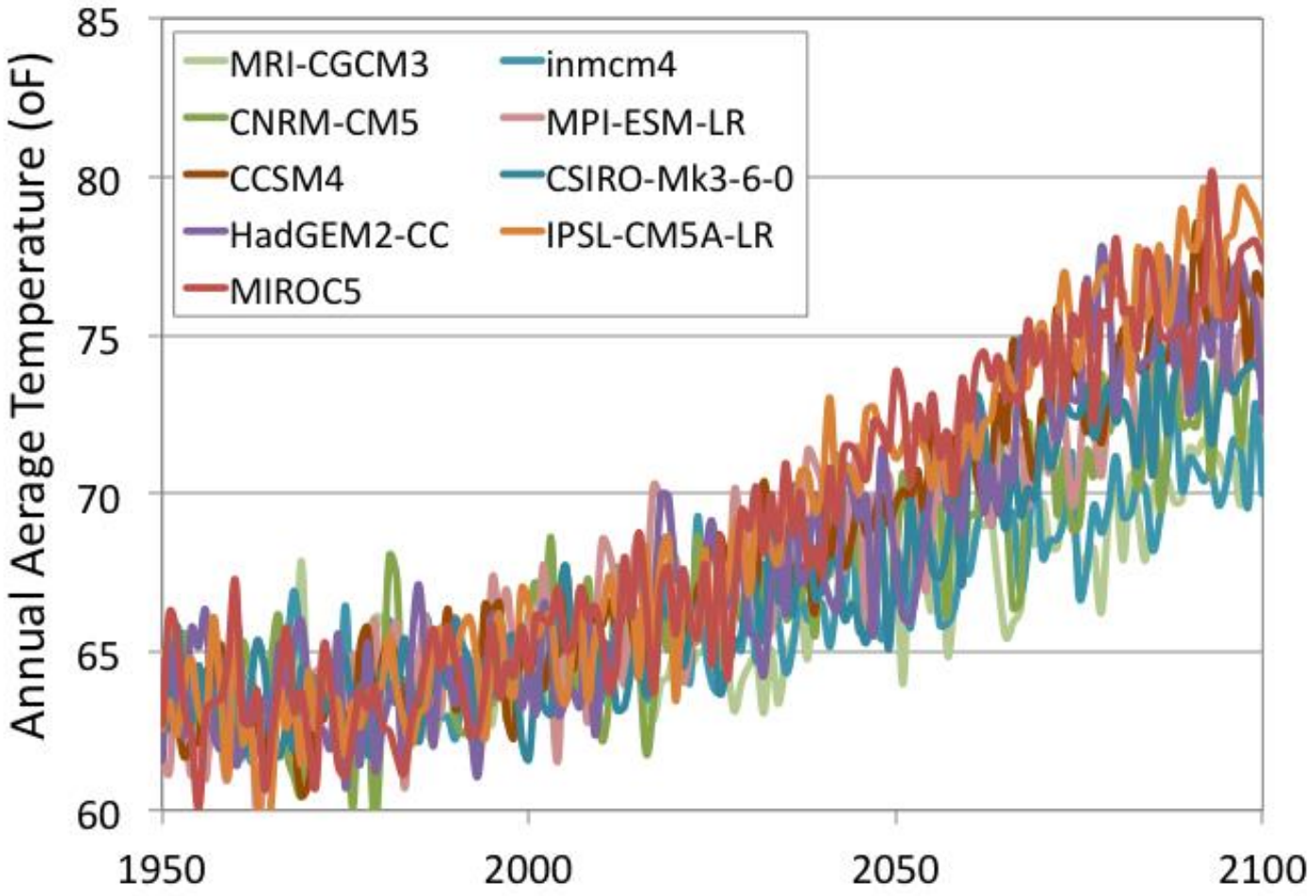
Climate Model Data

North American Regional Climate Change Assessment

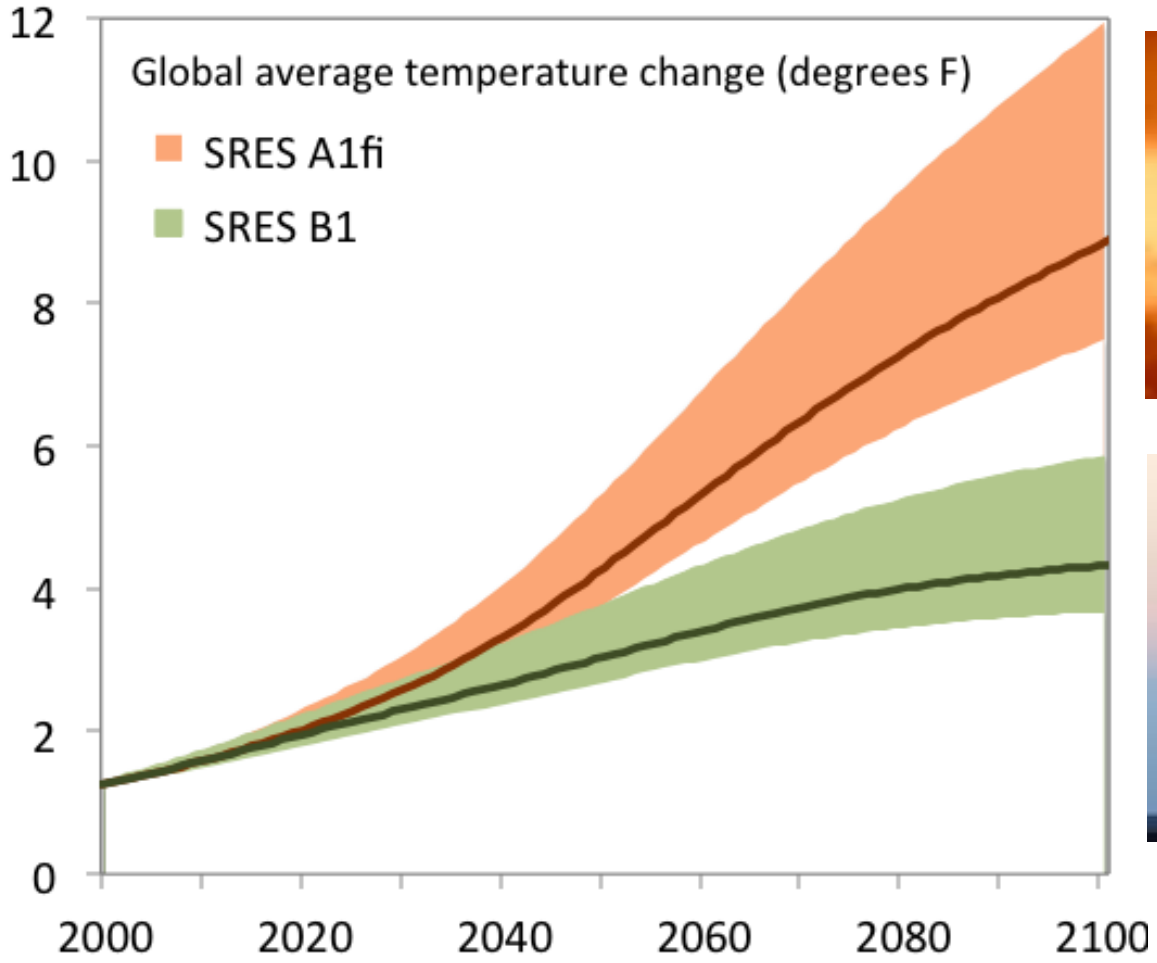
- Series of Regional Climate Models (RCMs)
- Spatial Resolution
  - ~ 50 x 50 km pixels
  - North America
- Temporal Resolution
  - Current : 1970 – 2000
  - Future: 2040 – 2070
  - 30 to 100 Year Records
  - 3-Hourly, Daily, & Weekly



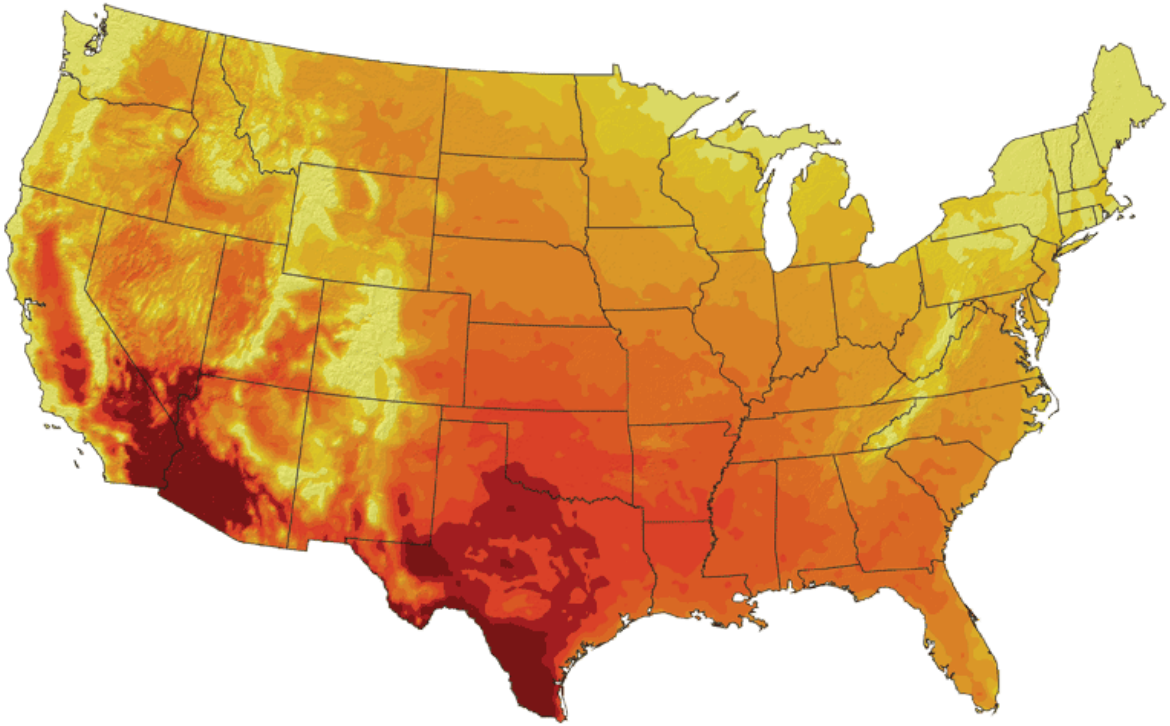
STEP ONE: Use multiple simulations and models from latest generation of global climate model simulations (CMIP5)

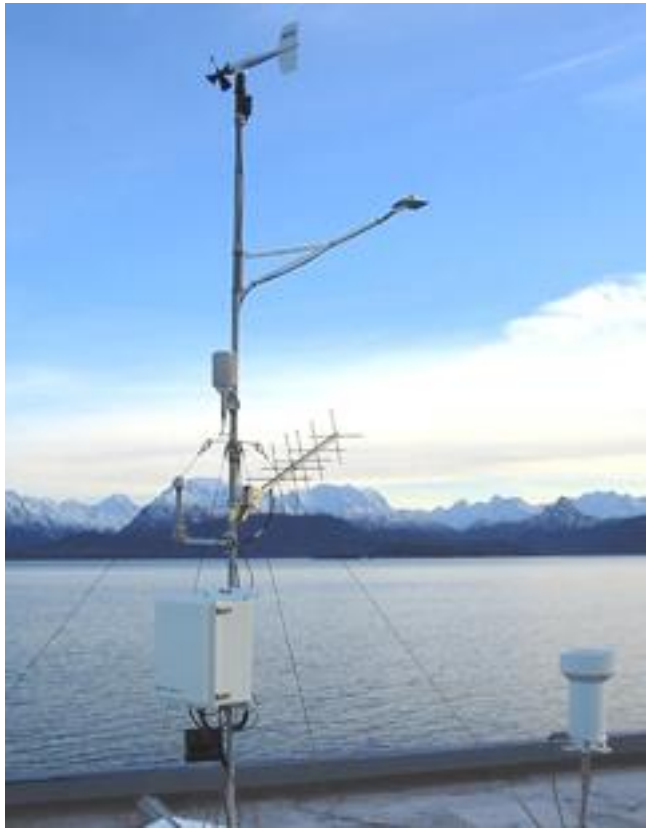


STEP TWO: Develop projections for multiple scenarios, from higher to lower



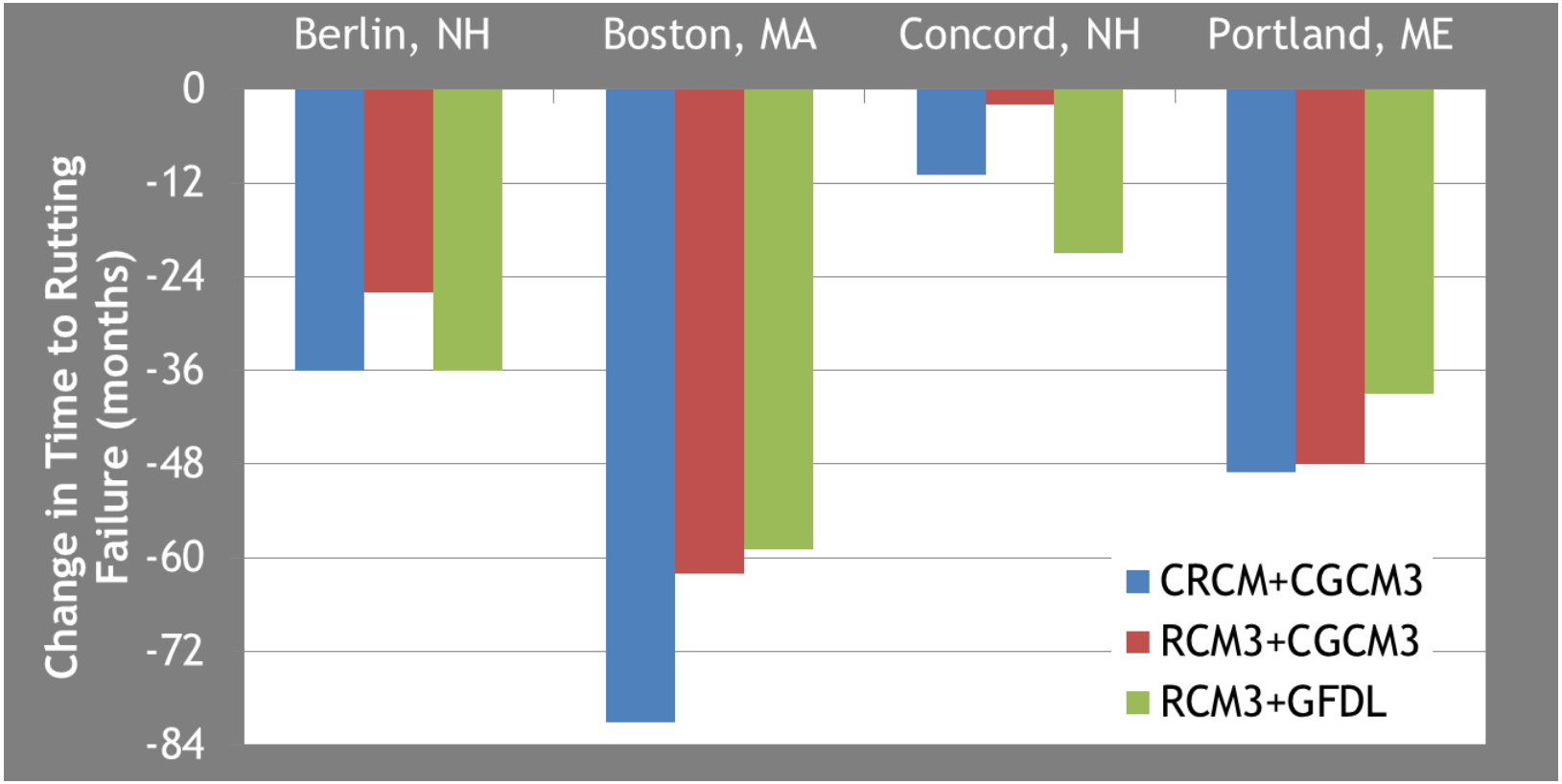
STEP THREE: Downscale to a continuous 1/16th degree grid or to local weather stations *selected by the planners, engineers, or users*





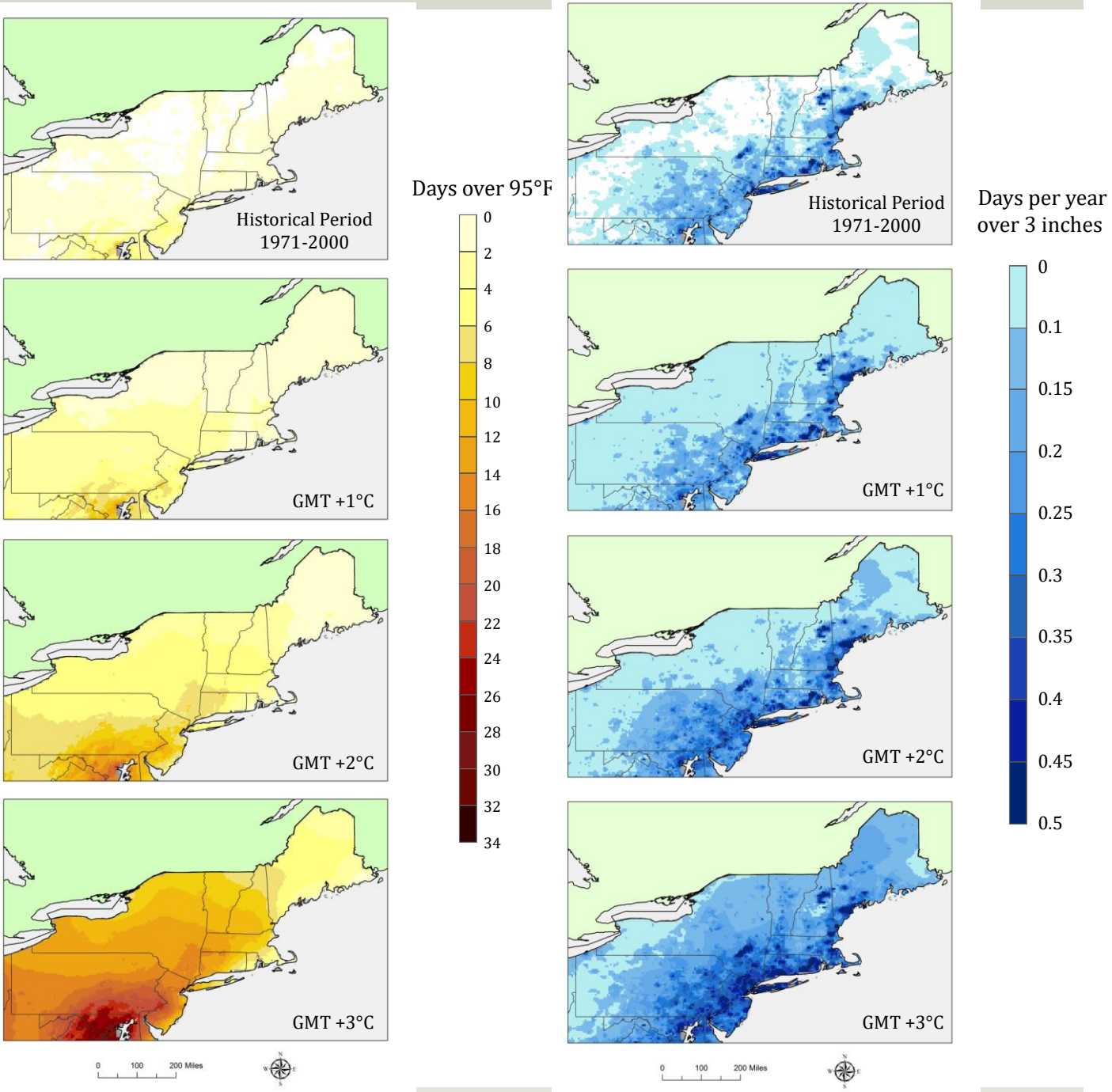
STEP FOUR : Develop projections for impact-relevant climate indicators

Temperature Impacts on Rutting Using MEPDG
Interstate Failure: Future - Current

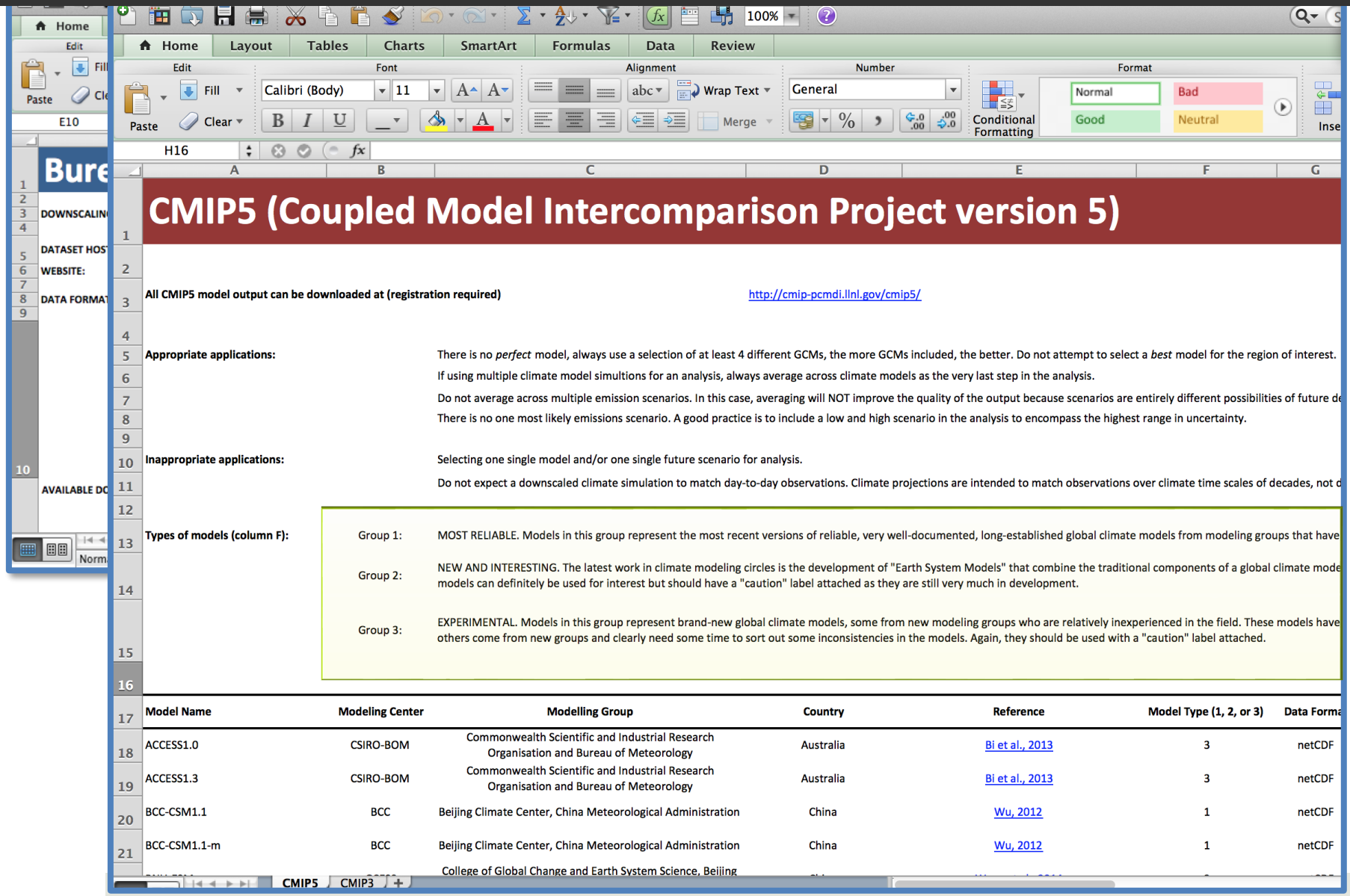


Meagher, W., J.S. Daniel, J. Jacobs, and E. Linder. 2012. Transportation Research Record, Vol. 2305/ 111-120.

For the Northeast, ICNet has developed a suite of general indicators



ICNet Resources: Research Tools



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 simultions 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 de

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 d

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

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 mode 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 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 Forma
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				

Built Infrastructure Thinking

- Resistance is not Resilience
- Safe to Fail, not Fail Safe
- Design with Nature

"A mix of local and regional actions taken over space and time by public and private organizations…"

Co-authors

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Sustainability and resilience depend on multi-institution collaborations to support the integration of climate science forecasts into engineering research for transportation infrastructure

THANK YOU!

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