



# Argonne National Laboratory

## Using Climate Data to Inform Critical Infrastructure Resilience and Urban Sustainability Decisionmaking

National Academy of Sciences Roundtable on Science and Technology for  
Sustainability

November 12, 2015





An aerial photograph of the Argonne National Laboratory campus. The image shows a large, modern, circular building with a white, ribbed roof, surrounded by green lawns and trees. Several other large, multi-story brick buildings are visible, along with parking lots and roads. The campus is situated in a wooded area with a highway running alongside it.

# Argonne National Laboratory

## Our People

- 3,398 total employees
- 1,395 scientists and engineers
- 303 postdoctoral scholars
- 940 graduate and undergrad students
- 230 joint faculty
- 6,500+ facility users

## Our Work

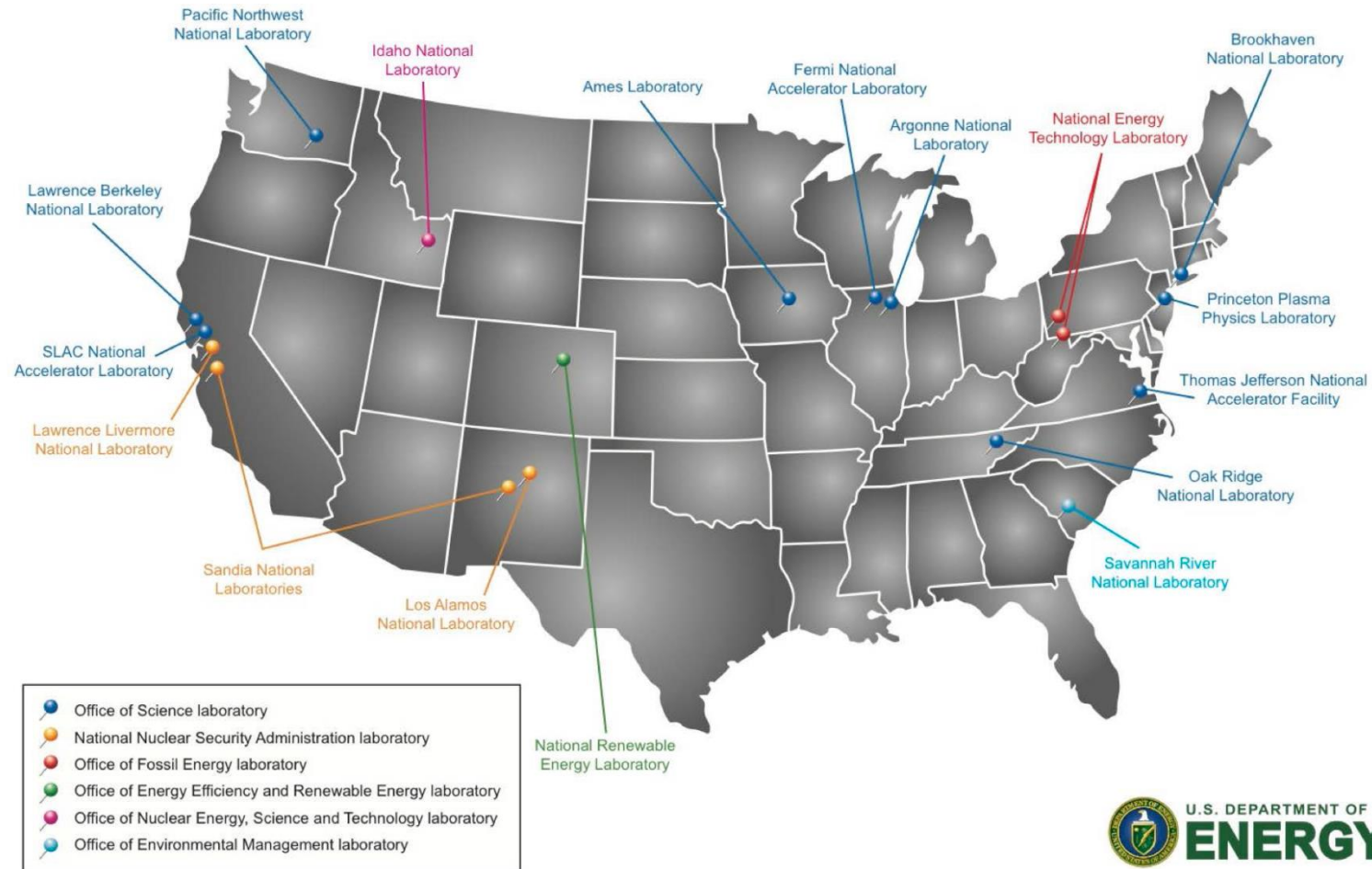
- 15 research divisions
- 5 national scientific user facilities
- Many centers, joint institutes, program offices
- Collaborations with more than 600 companies, numerous Federal agencies, and hundreds of research institutions worldwide

## Our Mission

Integrate world-class science, engineering, and user facilities to deliver innovative research and technologies. We create new knowledge that addresses the scientific and societal needs of our Nation.



# Argonne is a Member of the U.S. Department of Energy's National Laboratory Complex



# Risk and Infrastructure Science Center (RISC)

- Built on more than 20 years of critical infrastructure protection support to the U.S. Department of Energy (DOE), U.S. Department of Defense (DoD), President's Commission on Critical Infrastructure Protection (PCCIP), Department of Homeland Security (DHS), and other organizations
- Supports the critical national and homeland security priorities of a variety of Federal sponsors



# Cod's Continuing Decline Linked to Warming Gulf of Maine Waters

*But the quotas, the study's authors say, were based on population estimates that did not take into account the temperature changes and therefore were set too high. Even when fishermen stayed within the quotas, they were in effect overfishing, the researchers write in their report, which appears in the Oct. 30 issue of the journal Science.*

*"The failure to consider temperature impacts on Gulf of Maine cod recruitment created unrealistic expectations for how large this stock can be and how quickly it can rebuild," the researchers write.*

*—New York Times, October 30, 2015*

# The Climate Change Adaptation Challenge

- **The vast majority of infrastructure is still being designed for a static climate**
  - Design standards and tools use historical record (e.g., rainfall, temperature)
  - Standards drive design to avoid liability in the event of failure
  - However, unless design reflects a changing climate, failure is more likely
- **Barriers to climate change adaptation**
  - Lack of local-level modeling of temperature and precipitation changes,
  - Lack of high-resolution climate scenario data needed to justify starting adaptation projects, and
  - Lack of a local framework for adaptation planning (ACCO 2013)

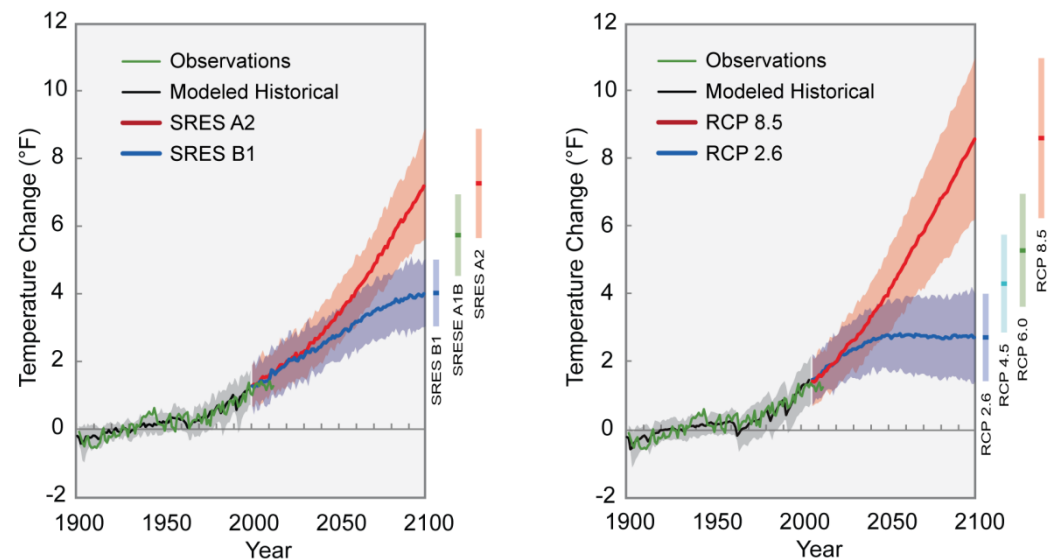
*“Two issues are lack of routinely available data that’s useful at the local scale and experts who can translate science-based findings into policy objectives. We simply don’t have that cadre built yet of knowledgeable people who can consult and offer the advice.”*

*—Alice Hill, National Security Council, White House, June 2015 speech on mainstreaming climate risks into U.S. Government Planning*

# The Gap between Climate Science and Critical Infrastructure Adaptation

- Available climate data are often developed by and for the atmospheric and oceanic science communities.
- Projections of future climate conditions are not easily translated into local climate impacts, yet these are the impacts that are more directly actionable through engineering design, infrastructure management, and urban planning practices.
- Urban planning and engineering design practices are currently not equipped to bridge the gap between climate model outputs and climate impact information necessary for adaptation.

Emissions Levels Determine Temperature Rises



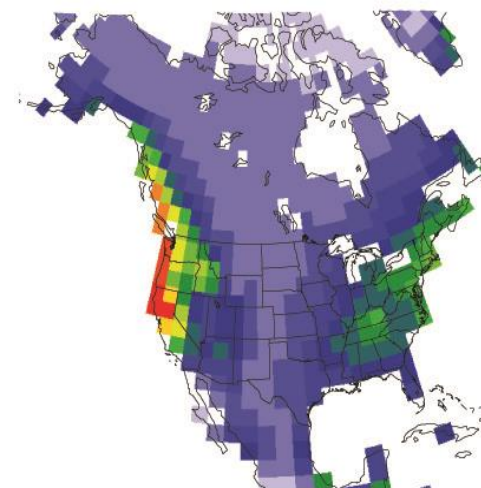
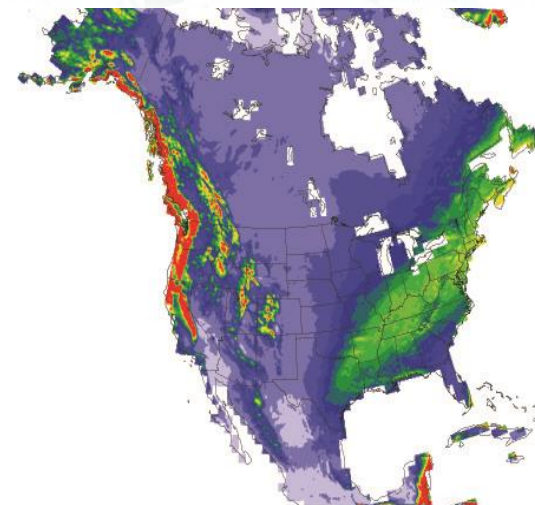
Source: National Climate Assessment (2014)



# Zooming In: From Global to Regional Climate Models

- Regional climate models (RCMs) allow researchers to better account for topographic details, while also improving the ability to simulate surface variables such as air temperature, precipitation, and wind.
- RCMs vastly improve modeling of climate over mountainous regions or other variable terrain.
- RCMs also run at a finer temporal resolution than global models, which provides output at a timescale that allows researchers to explore climate changes such as urban heat islands on diurnal scales.

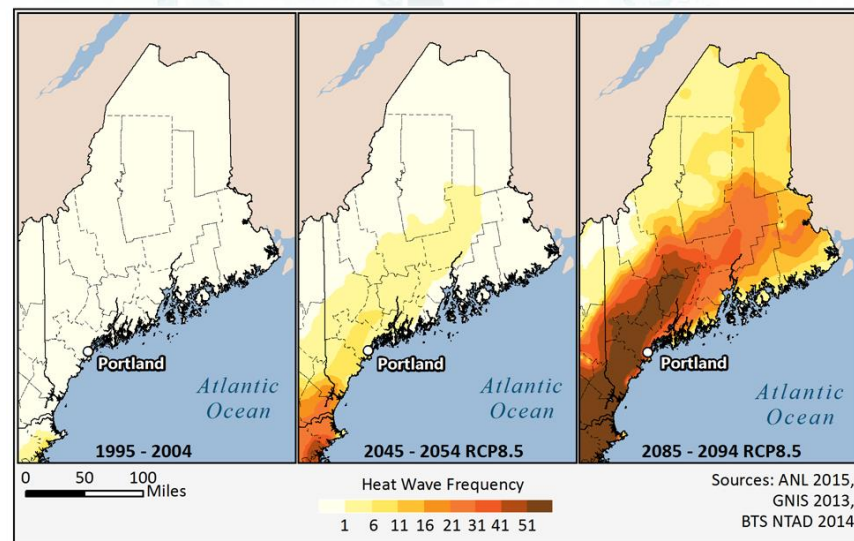
*Images show average winter precipitation rate (mm per day) for a 10-year period (1995 to 2004) as simulated by a RCM with 12-km spatial resolution (top) and a global climate model with 250-km spatial resolution (bottom).*



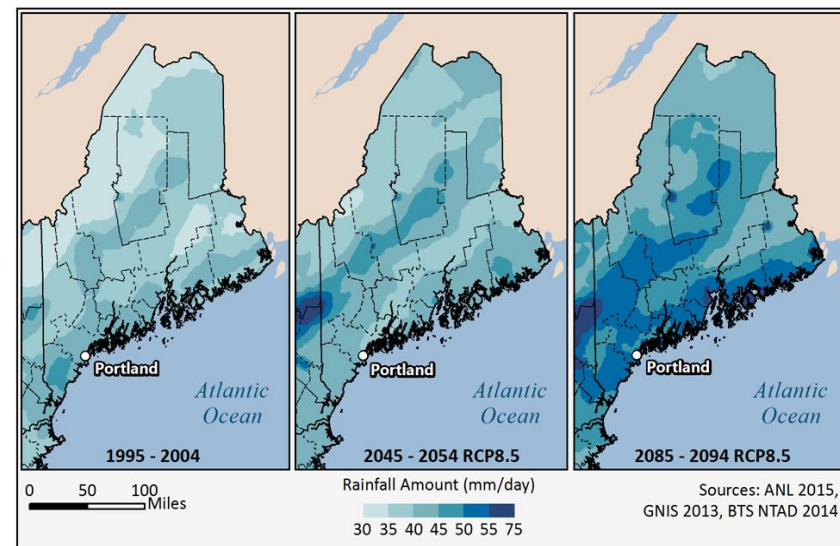


# Regional Climate Modeling

- Increased spatial resolution of climate model output: 1- to 2-degree grid (global scale) to 1/8-degree grids (regional scale)
- Downscaling involves using Argonne's supercomputing facility to perform multiple runs of a RCM
- Produces projections of the following:
  - Average and maximum annual precipitation
  - Average and maximum annual temperature
  - Other climate stressors identified by stakeholders
  - Multiple time slices: mid-century, end of century



Projected Trends in the Average Annual Number of Heatwaves



Projected Average Annual Maximum Precipitation (Greater than 99%)

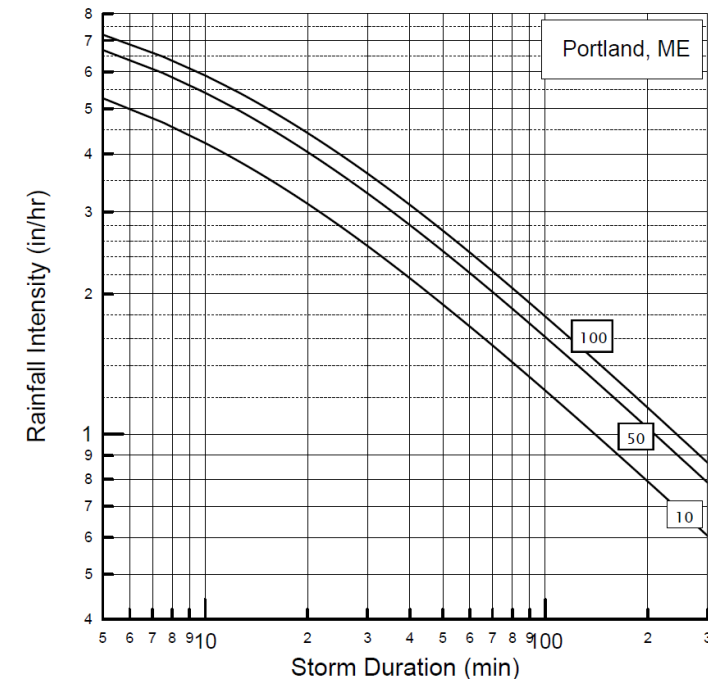
# Using Downscaled Climate Data to Drive Infrastructure Impact Models

- Infrastructure models (e.g., electric, natural gas, petroleum, water, transportation systems) can be coupled to climate models to assess climate hazards
- For example, Argonne is using the EPfast (electric) model as part of an analysis of the impacts of mid-century increased temperature on Maine's electric grid
  - Determine impacts on the capacity of power plants, transmission lines, and transformers, as well as growth in demand
  - Determine implications on overall grid performance via load flow simulation
  - Results show that increasing temperatures affect seasonal electricity demands (e.g., increased cooling demand in the summer) and power plant output and transmission line capacity, which could cause rolling brown-outs if electric infrastructure does not adapt

*Regional climate models, coupled with infrastructure modeling and analysis, can inform planning decisions that will result in more resilient infrastructure being designed and built in the future.*

# Generating Actionable Climate Data for Current Design Practices

- In many cases, climate data will require translation to inform infrastructure design
- For example, drainage systems may be designed for a 50-year flooding event (i.e., event that has an annualized average likelihood of occurrence of 2%)
- To consider climate change in drainage system design, engineers must first determine how the climate model output (precipitation) will translate hydrologically into surface-water runoff or flooding, and then determine to what extent the model output reflects extreme precipitation and runoff



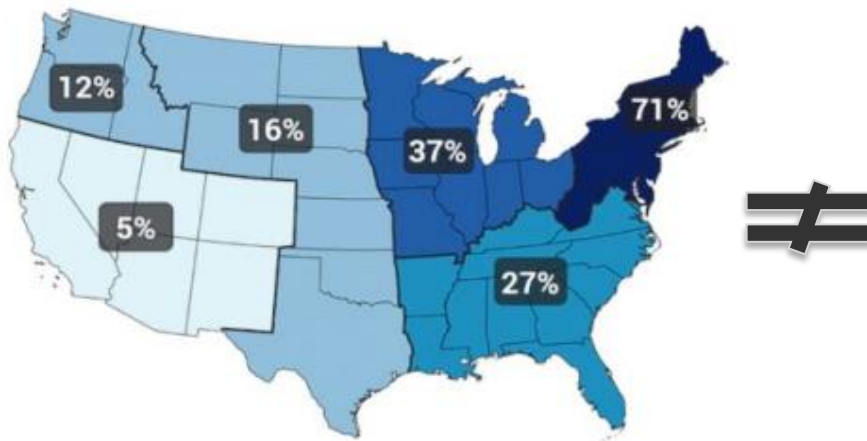
Source: State of Maine Urban & Arterial Highway Design Guide (2005)



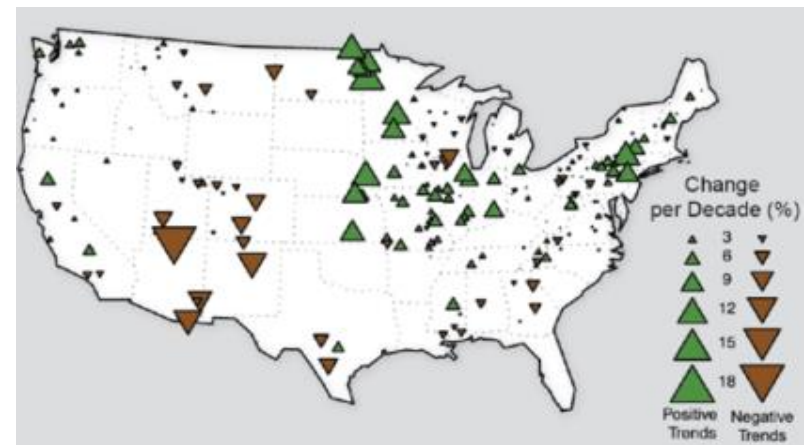
# Intensity-Duration-Frequency (IDF) Curves

- Next-generation intensity-duration-frequency (IDF) curves are one approach to incorporating climate data into hydrological modeling and design practices
  - IDF curves are widely used to develop the design basis for precipitation-affected infrastructure systems, engineering standards, and building codes and maintenance standards
- Precipitation frequency is not necessarily similar to flood frequency
  - Effect of drainage characteristics of the watershed, including human roles
  - Effect of snowfall and snowmelt

Observed Change in Heavy Precipitation from 1958 to 2012

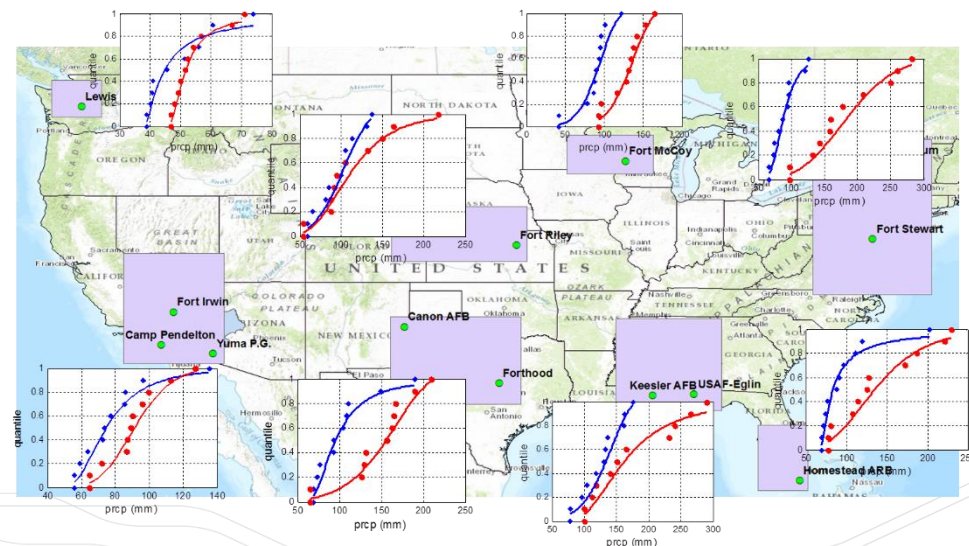


Annual Flood Magnitude from the 1920s through 2008



# IDF Curve Development (Cont.)

- Argonne has provided hydrologic analyses in support of multiple projects for the U.S. Nuclear Regulatory Commission and Department of Defense (DoD), including:
  - Hydrologic safety analyses for proposed facilities
  - Flooding re-evaluations in response to the Fukushima disaster
  - Hydrologic analyses for DoD management challenges and reduction of unnecessary impacts on military base missions and assets
- Similarly, cities should reanalyze their flood vulnerabilities in light of climate change



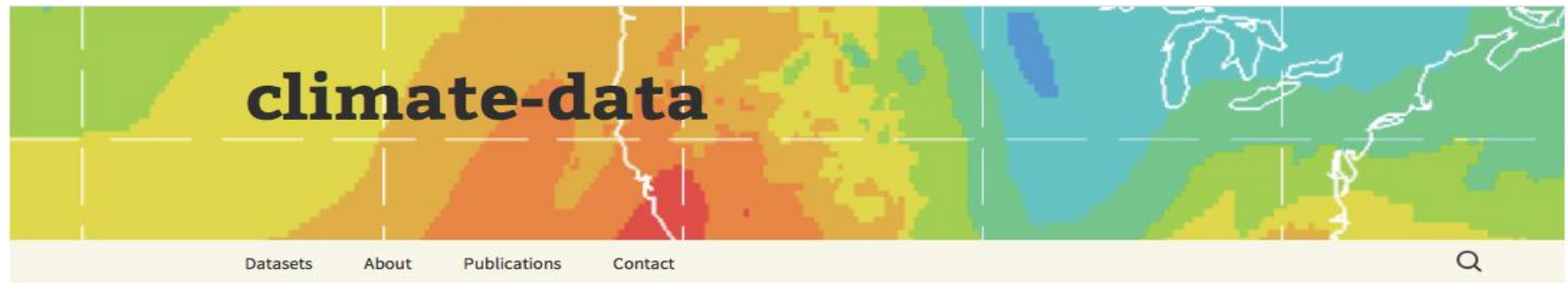
# Use of Climate Information for Decisionmaking and Impacts Research: State of Our Understanding (User Manual Forthcoming)

- A climate data user manual is being prepared for the DoD's Strategic Environmental Research and Development Program, and will provide planners and decision makers with:
  1. A critical overview of relevant downscaling models, methodologies, and data;
  2. The advantages and disadvantages of each method;
  3. Geographical dependence of bias for each method (e.g., systematic under- or over-prediction of climate impacts); and
  4. Uncertainties associated with the downscaling process and climate data in general (SERDP 2014)

*In collaboration with Texas Tech, the National Center for Atmospheric Research, Arizona State University, and the University of Illinois—Urbana-Champaign, Argonne is developing a users manual on how to use downscaled climate data.*



# Dissemination of Model Results (Data Portal) Using a Globus-based Data Distribution Model



## Welcome!

🕒 February 27, 2015   📁 Uncategorized   ✎ Edit

We have generated an RCM output at temporal and spatial resolution of 3 h and 12 km, respectively, covering much of North America. The model output is stored in the self-describing and machine independent NetCDF format.

We also project the future climate (2050s and 2080s) based on two different emission scenarios suggested by the fifth IPCC report and forced using boundary conditions from two separate climate models (CESM 1.0 and GFDL hiram). The project is supported by Department of Defense, SERDP program. The model output is also being used for regional scale resilience project (RRAP) project of the Department of Homeland Security as well as universities in the US.



# Regional Climate System Assessment Framework

## ARGONNE EXPERTISE

ENVIRONMENTAL SCIENCES

ENGINEERING & SYSTEMS

SOCIOECONOMICS & POLICY

SECURITY

## ARGONNE PARTNERSHIPS

- ▶ National Laboratories
- ▶ Universities
- ▶ Federal Organizations
- ▶ State, Local, Tribal, and Territorial Government
- ▶ Private Sector

STAKEHOLDER NEEDS AND REQUIREMENTS

SCOPE GOALS AND OBJECTIVES

**STAKEHOLDER-DRIVEN ANALYSIS**  
Regional & Infrastructure Resilience Analyses  
Risk Analyses  
Cascading Failure Analyses

FINAL PRODUCTS

- ▶ Decision Support
- ▶ Local Climate Change Data
- ▶ Simulation Tool
- ▶ Adaptation Plans
- ▶ Training and Exercise
- ▶ Intelligence Fusion

ANALYSIS CAPABILITIES AND SUPPORT

DATA

- ▶ NOAA
- ▶ USGS
- ▶ DHS
- ▶ Critical Infrastructure
- ▶ Other

MODELS AND TOOLS

- ▶ Global and Regional Climate Models
- ▶ Infrastructure Impact Models
- ▶ Infrastructure Dependency and Interdependency Tools
- ▶ Economic Models
- ▶ Social Science Models
- ▶ Restoration and Recovery Tools
- ▶ Physical Processes Models

## ARGONNE EXPERTISE

### ENVIRONMENTAL SCIENCES

- ▶ Atmospheric and Climate Sciences
- ▶ Earth Sciences
- ▶ Oceanography
- ▶ Space Sciences

### ENGINEERING & SYSTEMS

- ▶ GIS
- ▶ Modeling of Complex Systems
- ▶ Infrastructure System Analysis
- ▶ Operations Research
- ▶ Vulnerability Assessment
- ▶ Resilience Assessment
- ▶ Emergency Management
- ▶ Energy Sciences

### SOCIOECONOMICS & POLICY

- ▶ Land Use/ Development
- ▶ Human and Social Sciences
- ▶ Economic Sciences
- ▶ Political Sciences
- ▶ Policy Analysis
- ▶ Risk Communication
- ▶ Information Sharing

### SECURITY

- ▶ National Security
- ▶ Homeland Security
- ▶ Intelligence

**For more information, please contact:**

Duane Verner, AICP  
Risk and Infrastructure Science Center  
Global Security Sciences Division  
Argonne National Laboratory  
919-368-4908  
[dverner@anl.gov](mailto:dverner@anl.gov)