Climate Explorer

Improved Access to Local Climate Projections

Adapted from "Climate Explorer: Improved Access to Local Climate Projections," by **Fredric Lipschultz** (U.S. Global Change Research Program), **David D. Herring, Andrea J. Ray, Jay Alder, LuAnn Dahlman, Arthur DeGaetano, James F. Fox, Edward Gardiner, Jamie Herring, Jeff Hicks, Forrest Melton, Philip E. Morefield, and William V. Sweet.** Published online in *BAMS*, March 2020. For the full, citable article, see [DOI:10.1175/BAMS-D-18-0298.1](https://doi.org/10.1175/BAMS-D-18-0298.1).

The burgeoning interest in climate information extends to many uses. For example, financial firms use climate information about extreme events to inform investment strategies, and consulting firms now model climate risk or link municipal bond ratings to exposures to climate-related hazards.

Decision-makers utilizing both observed and projected climate data need a brokered connection to authoritative and carefully vetted information so they can comply with legal mandates and execute smart decisions. The Climate Explorer (CE), an integral part of the U.S. Climate Resilience Toolkit (CRT), can help by offering the best available climate projections in an intuitive presentation that supports a wide range of decisions.

Responding to increased demand for climate data and information, the U.S. Global Change Research Program (USGCRP) efforts have shifted over the past decade from documenting impacts to informing and supporting decisions. The CRT was initiated in 2015 under the auspices of the USGCRP and hosted by NOAA to help people determine whether valued assets are at risk from climate-related hazards, and if so, how they can build resilience. The CRT builds on the Fourth National Climate Assessment (NCA4), linking its authoritative results and core datasets so that governmental entities, nongovernmental organizations, businesses, and individuals can make better decisions using publicly funded, well-vetted climate science within a consistent framework.

An open-source, web-based mapping and graphing tool that delivers visualizations and raw data as well as presentation-ready graphics, the CE aims to bridge multiple disciplines, economic sectors, research, and applications by bringing current climate science to the desktops of decision-makers. It comprises several

curated datasets, including gridded historical weather observations, data from NOAA's Global Historical Climatology Network (GHCN) weather stations and tide gauges, and down-scaled climate projections used within the NCA4. The CE is made possible by advanced data-serving and analysis web services from the Applied Climate Information System (ACIS) used by NOAA's Regional Climate Centers.

Though the CE has offered downscaled climate projections for only the last three years, we see evidence that municipal planners, decision-makers, and adaptation consultants are using the tool in their work. For example, to support her city's climate resilience deliberations, Carol Davis, the sustainability manager for the city of Blacksburg, Virginia, used the CE to assemble a 31-page presentation featuring 22 separate maps and graphs taken directly from the tool. The CE helped Davis and her constituents consider the differing risks of two emissions scenarios on two time horizons in which climate-related hazards could impact their agricultural productivity and forest health and, in turn, their local economy.

In another example, Lara Hansen, executive director and chief scientist of EcoAdapt—a nonprofit consulting entity offering adaptation and decision support services—has incorporated the CE into her work for eight different municipalities. Hansen observes that

▲ **The home page of the Climate Explorer (<https://climateexplorer3.nemac.org>) lets users select a location and then choose from a list of climate variables or view charts from weather and tidal stations.**

“in most locations there is not customized local climate data to inform decision-making. Only large cities, such as New York, or data-rich regions, such as California or the Puget Sound region of Washington State, have the resources to create their own climate data. Prior to the Climate Resiliency Toolkit and the Climate Explorer, every other region was at a loss for where to go. Conducting comparisons between sites was a major undertaking.” Now, Hansen says, she uses the CE to help her provide the basic information smaller communities need to develop a climate-savvy plan.

Key design considerations

For downscaled climate projections, the CE adopted the Localized Constructed Analogs (LOCA) dataset because it improves representation of extremes and is the same climate product used in NCA4. We feel that a county-scale spatial resolution balances the need for locally relevant data without overwhelming users with difficult choices about how to interpret and summarize high-resolution data. Decision-makers who require higher-resolution data can retrieve the 1/16° spatial resolution LOCA dataset for analysis. The LOCA projections help users envision possible outcomes in two scenarios as those used in NCA4 and other federal reports: a higher (RCP8.5) and a lower (RCP4.5) greenhouse gas future. In particular,

▲ * Average annual daily maximum temperatures in Denver County, Colorado. Historical observations (dark gray bars) are generally within the envelopes of hindcasts (modeled historical values in gray). Projections are shown for both higher (red) and lower (blue) emissions scenarios. The red and blue solid lines show the weighted average of projected values under these two scenarios. The graph can be customized by changing the time scale and by hiding specified graphical elements.

we were cognizant that planners and decision-makers with a moderate to low tolerance for risk prefer to focus on a range of model outputs that best represents the more extreme possible futures represented by the RCPs.

The CE displays the full range of down-scaled projection values from 32 different global climate models (GCMs) used in phase 5 of the World Climate Research Program's (WCRP) Coupled Model Intercomparison Project (CMIP5). Providing the full range of values illustrates potential tail risks of the climate data. Users can also choose to show the weighted average of projected values from each GCM in a method of providing a weighted mean that was also a feature of NCA4.

The CE enables users to compare "hindcast" model outputs (i.e., historical modeling experiments from 1950 to 2005) with annually averaged, spatially gridded observations accounting for issues such as elevation. This capability gives users an opportunity to see if the climate models realistically capture the local, average weather conditions.

To assist users, short "tours" embedded in the interface describe features of the graphs

Climate variables in the Climate Explorer

Temperature

- Average daily maximum (annual, monthly, seasonal)
- Average daily minimum (annual, monthly, seasonal)
- Days with maximum >90°, 95°, 100°, 105°F
- Annual Days with minimum >80°, 90°F
- Days with maximum <32°F (icing days)
- Days with minimum <32°F (annual number of frost days)
- Growing degree days (GDD)
- Modified GDD
- Cooling and heating degree days

Precipitation

- Total (annual, monthly, seasonal)
- Days with >1, 2, 3 in.
- Dry days per year (with respect to threshold)

Sea level

- Annual days with high-tide flooding (only for NOAA tide gauge stations)

.....

¹ Directly access the data via online requests to ACIS web services (www.rcc-acis.org/doc_webservices.html). The open-source code for the CE's graph and map widgets is freely available (at <https://github.com/nemac/climate-widget-graph>), as is the code for the LOCA-derived variables (<https://github.com/rcc-acis/grid-reduce>).

and clarify the meaning of climate variables. Extensive documentation of the CE's datasets is also available, and data behind the maps and graphs are freely available for download at their full native resolution.¹

The CE offers observations and projections for about 20 decision-relevant climate variables. Users can check the average number of days per year projected to exceed temperature and precipitation thresholds via either a graph or a map, both of which respond dynamically to user specifications. The range of threshold

values helps ensure users explore exceedance of values that are relevant to their location. The CE enables users to chart daily observations of high and low temperature, and the cumulative pattern of annual rainfall, in comparison to 30-year averages. These data are available from ACIS for thousands of GHCN stations across the United States. Users can customize the interactive graphs to explore how year-to-year variability in weather compares to the long-term average for each location.

To promote awareness of coastal flooding, the CE provides graphs of past and projected changes in the frequency of high-tide flooding for most NOAA tide gauge stations. Users can now view the observed number of days annually with high-tide flooding at selected stations, and how frequencies are likely to increase

under the same two emissions scenarios used in NCA4.

Because the same essential climate data underlies both NCA4 and the CE, users can readily transition from the static maps and graphs within the NCA4 website to the CE, where they can dynamically and interactively explore the same data at higher spatial scales, customizing the maps and graphs. Additionally, most chapters and many case studies in NCA4 are linked to parallel themes, regions, and case studies on the CRT website, so users can explore more deeply within and across their regional, economic, and social interests.

Ongoing development

We continue to improve the CE in response to feedback from planners and decision-makers.

(bottom) From a static map * on the NCA4 website, clicking on the world icon in the upper upper-right corner opens the same dataset (LOCA) (top) within the CE, enabling the reader to explore the same variable (Days > 90°F in this example) for anywhere in the contiguous United States at the county scale and to customize the map or graph. The same icon attached to NCA4 case studies also leads to related CRT content. The “swipe” feature in the CE map lets users compare historical conditions (1961–90 average shown here) to decadal averages of projections (decade of 2090 shown here) for either emissions scenarios. The interface permits users to select the time period or to graph data for any county in the conterminous United States.

NCA4

Figure 25.10: Projected Increases in Extreme Heat

We are actively coordinating with regional experts to incorporate data for Alaska, Hawaii, and U.S. territories. Another enhancement we envision includes refining the ability of users to set thresholds of interest for their locations and assets.

The CE's underlying code is open-source to support widening its circle of contributors. By providing easy access to authoritative information in an elegant interface, the Climate Explorer can help communities recognize and prepare to avoid or respond to emerging climate hazards. ●●

≡ METADATA

BAMS: What is the achievement represented by Climate Explorer?

Fredric Lipschultz (U.S. Global Change Research Program): *The Climate Explorer and CRT reflect targeted, coordinated efforts by the federal agencies to improve the provision of climate information and build resilience by leveraging their datasets and expertise. Deliberately linking the CRT and National Climate Assessment, both authoritative sources, amplifies each and hopefully moves more people to take action.*

Art DeGaetano (Northeast Regional Climate Center, Cornell University): *Through tools like Climate Explorer, the voluminous datasets routinely used by climate scientists can easily be distilled into useful, user-friendly climate products.*

BAMS: What's the article's overarching message, then...to climate information users?

LuAnn Dahlman (NOAA): *Climate projections are complex and imperfect representations of reality. Nonetheless, they have successfully predicted the correct direction and magnitude of temperature changes over several decades. Climate models are the closest thing we have to a crystal ball for predicting our future climate.*

BAMS: How did you become interested in developing Climate Explorer?

FL: *After working on the 3rd National Climate Assessment,*

I realized that the definitive report, while useful, did not provide a path for readers to access more useable and locally-relevant information that would support their effort to build climate resilience. Since the CRT content was built on NCA3 content, it was apparent that we could deliberately leverage the Climate Explorer to provide that path.

BAMS: What surprises you the most about the development process?

FL: *Our team of federal scientists with diverse points of view and different expertise met regularly with the CRT development team to hash out a wide range of issues, from conceptual to highly technical. I have certainly learned a lot from everyone involved and greatly enjoy the camaraderie and interplay between our different viewpoints!*

AD: *The camaraderie we developed as a team. We each brought our own backgrounds and specialties, and by working together produced something that was clearly greater than the sum of our parts.*

BAMS: What was the biggest challenge you encountered while creating Climate Explorer?

FL: *Keeping focused on the big picture while working through all of the myriad issues to reach our vision for an effective tool that was intimately linked with another major interagency project—*

developing the 4th National Climate Assessment.

AD: *As always there were issues related to funding, including the resources required to keep Climate Explorer running beyond the terms of a conventional grant cycle.*

FL: *Also, it is a long and difficult process to carefully traverse the translation of science for a diverse audience.*

LD: *The whole team wrestled with how to translate scientific expertise and numerical results of climate model experiments into practical guidance for people who are not scientists. Whereas climate modeling experts feel it's important to spell out all the caveats for using projections, decision-makers are eager for definitive guidance about what they should expect in the future. Deciding how to show information that honors both these goals is an ongoing challenge.*

BAMS: What's next? How will you follow up?

FL: *In the short-term we are adding new variables and expanding to include coverage of Alaska and both the Pacific and Atlantic islands. We are also working to connect additional datasets for users to explore their vulnerabilities to the climate variables in the CE, and have started thinking about how to deepen the linkage with the next National Climate Assessment.*

AMS titles now available as eBooks at **springer.com**

AMS BOOKS

RESEARCH APPLICATIONS HISTORY

www.ametsoc.org/amsbookstore

Scan to see
AMS eBook titles
at springer.com

AMERICAN METEOROLOGICAL SOCIETY