BAMS Essay

The Regional Climate Center Program—Past, Present, and Future: Reflections from 40 Years of Regional Climate Services

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ABSTRACT: Since its inception in 1983, NOAA's Regional Climate Center (RCC) Program has been providing timely, customized climate services for decision making across all climate-sensitive sectors. Through this 40-yr period, the RCC Program has not only seen but also has played an active role in, the evolution of climate services from the days of climate data libraries—where books of data were consulted to fulfill simple data requests—to coproduced tools that can calculate sectoral-specific, on-the-fly climate analyses in a matter of seconds. With new technologies emerging, the RCC Program is poised to build on its reputation as a trusted climate service provider by incorporating advanced methods for climate service delivery to continue to meet the needs of the nation. This publication will provide a look back at the evolution of regional climate services over the past 40 years, along with a vision for the future.

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1. Celebrating 40 years of the Regional Climate Center Program

The Regional Climate Center (RCC) Program has its roots in the National Climate Program Act of 1978, which recognized the need for expanding access to regional climate information in support of a range of stakeholders. At the time, there was a growing interest in applied climatology, and a gap between local and national climate service providers existed. A new concept—a regional climate service program—was tested through pilot projects in the early 1980s in the north-central and northeastern regions of the United States (Changnon et al. 1990; DeGaetano et al. 2010). After a short demonstration period, the RCC Program began to be formally established, with the creation of the Northeast RCC at Cornell University in September 1983. Over the next several years, the RCC Program grew to collectively serve all 50 U.S. states, the U.S. territories, and Washington, D.C. (Fig. 1). (For a timeline of major events in the RCC Program's 40-yr history, please see https://www.srcc.tamu.edu/about_us/regional_climate_centers/.)

During the 40-yr tenure of the program, the RCCs have engaged in a wide variety of activities that support their role as trusted operational climate service providers. With the aim to transform climate data into regionally relevant information that is useful, usable, and used, the RCCs continuously work to provide enhanced climate services by engaging with partners and stakeholders to better understand emerging climate-related needs, conducting user-inspired applied climate research, developing climate data and information decision-support tools, and engaging in climate data stewardship activities that improve the quality and availability of data. Through time, as outlined in DeGaetano et al. (2010), the program has come to fill three main niches:

- Provision and development of sector-specific and value-added data products and services.
- Establishment of robust and efficient computer-based infrastructure for providing climate information.
- Seamless integration and storage of non–National Oceanic and Atmospheric Administration (NOAA) climate data with traditional NOAA data sources.

The collaborative nature of the RCCs work is exemplified in its close working relationships with public and private partners and stakeholders, as well as other state, regional, and national climate services providers. For instance, the RCC Program has enjoyed partnerships with State Climate Offices (SCOs), NOAA's National Weather Service (NWS), the U.S. Department of Agriculture's Natural Resources Conservation Service (USDA NRCS), and NOAA's National Centers for Environmental Information (NCEI). The collocation of most RCCs with SCOs has fostered long-lasting, deep relationships at the state level, in particular. More recently, as the need for more climate adaptation-centered services has arisen, the RCCs have embraced

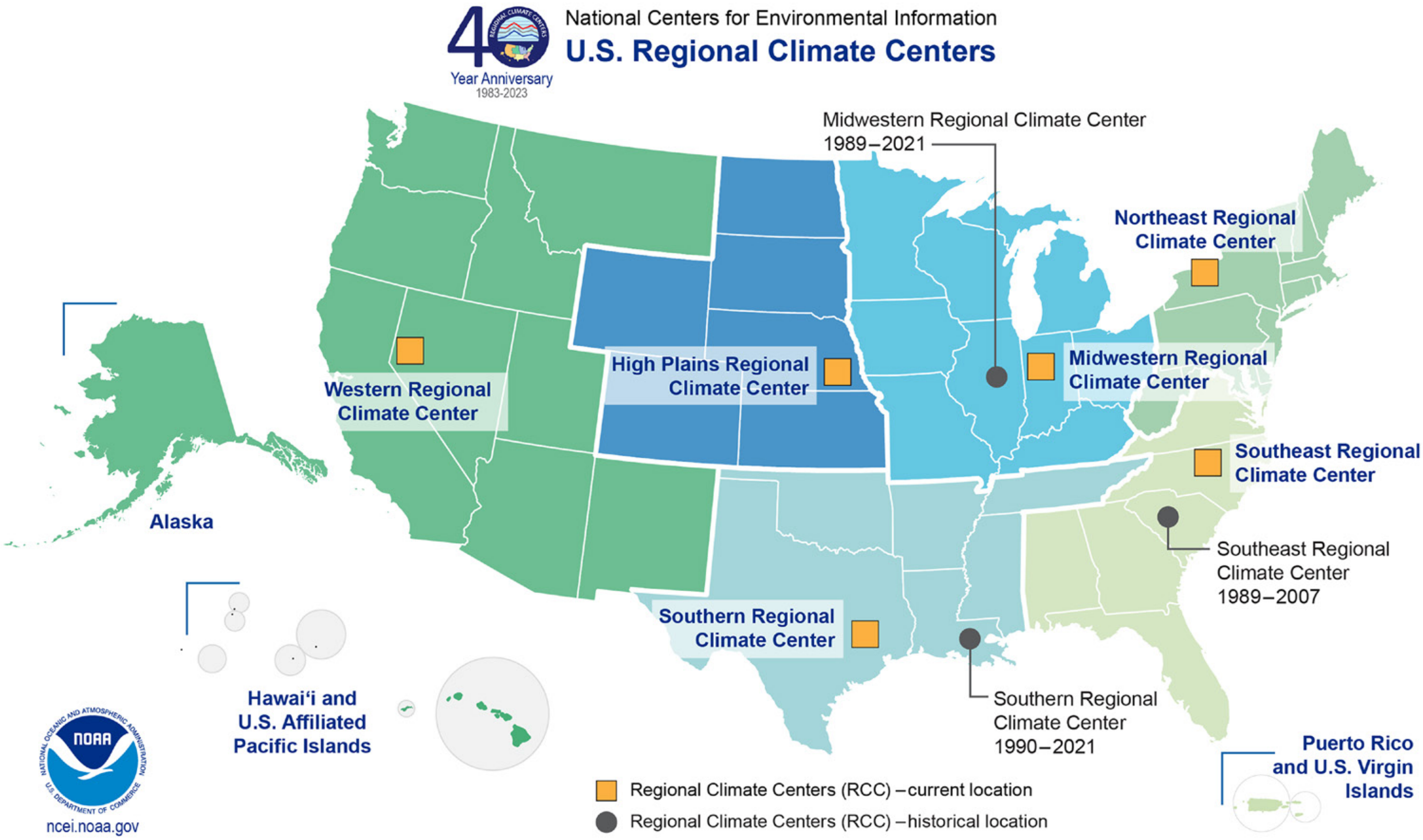

Fig. 1. Current and former locations of the six RCCs, along with their service regions. These include, from west to east, the WRCC at the Desert Research Institute in Reno, NV; the HPRCC at the University of Nebraska–Lincoln in Lincoln, NE; the SRCC at Texas A&M University in College Station, TX; the MRCC at Purdue University in West Lafayette, IN; the SERCC at the University of North Carolina at Chapel Hill in Chapel Hill, NC; and the NRCC at Cornell University in Ithaca, NY.

the opportunity to partner extensively with other, newer regional climate service providers, such as the NOAA Climate Adaptation Partnerships/Regional Integrated Sciences and Assessments (CAP/RISAs), the USDA Climate Hubs, and the U.S. Geological Survey (USGS) Climate Adaptation Science Centers (CASCs).

Base funding for the RCC Program is provided through a competitive contract with NOAA through NCEI. Each RCC is housed at a university, and additional funding is often pursued to meet emerging research and engagement needs in each region. This flexibility has helped the RCCs become a nimble program that allows for the delivery of a substantial breadth of efficient, user-driven climate services for *any* sector, from local to national scales.

2. Evolution of climate services

The provision of climate services has changed dramatically since the decade the RCC Program was established. At the time, the vast majority of weather and climate data were archived in libraries housing data that were handwritten on paper forms, printed in books, or stored on various forms of media, such as microfilm and microfiche (Fig. 2). Aside from the expansive holdings at the National Climatic Data Center (NCDC, now a part of NCEI), each RCC had its own library, as did many SCOs and NWS Weather Forecast Offices. With the digitization of weather and climate data in its relative infancy, users in need of data or data analyses had relatively few options for obtaining it.

At the RCCs, one option was, and still is, to engage with staff directly, typically via phone, fax, mail, or e-mail. RCC staff work one-on-one with requestors to understand the specific application of climate data that is needed, identify the most appropriate data to use for that application, and help the requestor understand the data and its limitations. In the early days

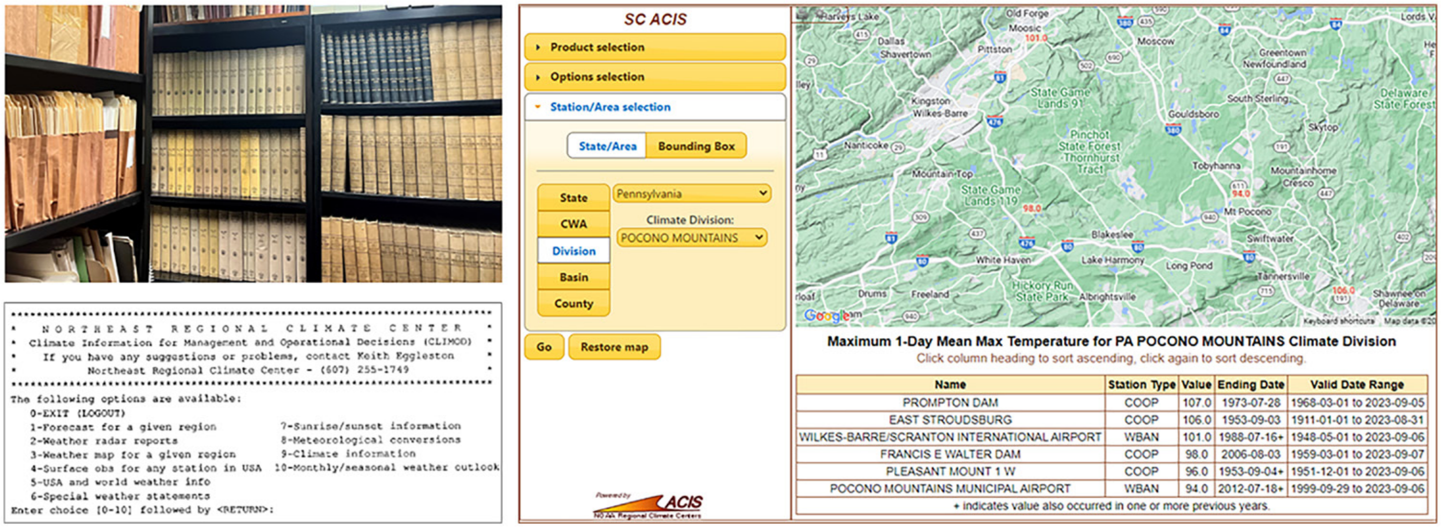

Fig. 2. (top left) Climate data library at the HPRCC, which includes data going back to the late 1800s; (bottom left) menu options from the original version of CLIMOD, circa late 1980s; (right) SC ACIS online interface, which allows access to station data, gridded data, and a number of analyses.

of the Program, staff would typically provide this guidance along with physical copies of data, but analyses were usually fairly limited due to constraints in technology and a lack of digital data. Today, RCC staff continue to engage directly with requestors to address climate-related issues, but now there are numerous online resources available to assist with the process. Over the years, these requests, along with other sustained engagements with partners and stakeholders, have given RCC staff insight into myriad ways in which climate data are being used. This insight, coupled with the RCCs deep knowledge of climate data and its use in applications, continues to inform the creation of climate data retrieval and analysis tools to this day.

The other option was to connect to localized RCC data storage systems that contained a combination of near-real-time data and data that were hand key-entered from paper forms. Early versions of these systems included Climate Information for Management and Operational Decisions (CLIMOD; Fig. 2), developed at the Northeast RCC (NRCC), and Climate Assistance Service (CLASS), developed at the Illinois State Water Survey for the pilot project that would become the Midwestern RCC (MRCC). Systems like these became more sophisticated over time by taking advantage of new technologies to incorporate and disseminate additional datasets and sector-specific analyses, such as innovative agro-climate products like soil moisture estimates and crop yield probability assessments (Kunkel et al. 1990).

Local, disparate data retrieval systems served the needs of many throughout the years, in fact, some still do; however, a gap remained for those looking for climate data that crossed RCC boundaries, especially as the volume of available data rapidly increased. In the 1990s, the RCCs began crafting an Internet-based integrated data system that would allow for the dissemination of up-to-date climate information through the efficient and effective exchange of climate data and tools across the six RCCs, as well as synchronization with the national archives at NCDC. With seed funding from the USDA NRCS, the RCC Program developed the Unified Climate Access Network (UCAN), later rebranded as the Applied Climate Information System (ACIS), which was a first-of-its-kind system for the management, delivery, and analysis of climate data. When it became operational in about 2000, UCAN/ACIS had capabilities that were previously out of reach. Users could obtain near-real-time data from multiple datasets across the country, use ACIS-based tools to perform analyses and visualize data (Fig. 2), and even use ACIS as the underlying data source for their own online tools. What would previously take hours upon hours to complete could now be done in a matter of seconds.

Fast-forward to today, and there has been an exponential increase in the amount of data that are available online. When the RCCs were established, many state and regional networks of closely spaced automated stations, or mesonets, were also just getting started (Mahmood et al. 2017). In fact, several national networks that supply data for modern climate services were years away from inception, such as Automated Surface Observing Systems (ASOSs), the Climate Reference Network (CRN), and the Community Collaborative Rain, Hail and Snow Network (CoCoRaHS). Many data digitization and recovery efforts were also years away from implementation; however, some RCCs were at the forefront of early efforts (e.g., Kunkel et al. 1998). Due to years of work developing cutting edge data ingest and quality control techniques, as well as the development of ACIS, the RCCs were well positioned to ingest and deliver data from these new, or newly digitized, datasets when they became available. Now, numerous datasets, analyses, and tools available from the RCCs—many of which are much more sophisticated than in previous years, incorporating gridded datasets, weather forecasts, and climate projections—can be accessed with just a few taps on a smartphone.

This shift in availability and accessibility of climate data has changed not only what climate services the RCCs provide but also the way in which they are provided, moving largely away from the need for climate service providers to serve as intermediaries. This "self-service" model works well for many users. In addition to millions of hits to RCC web pages each year, ACIS servers respond to over 1.5 million data requests per day alone. Over the years, the RCCs have worked with partners, like the NWS, to develop customized tools for their users under this model, e.g., NOAA Online Weather Data (NOWData; https://sercc.com/noaa-online-weather/). Even with a move toward a self-service model, engagement with climate data users remains an integral part of RCC climate services and continues to drive the development of new applied climate research projects and decision-support tools that help meet user needs (Fig. 3).

3. User-driven services in action

Many of the services that the RCC Program provides are built around special emphasis areas that are locally relevant. These include water resources, wildland fire, and coastal/ocean resources including sea level rise and coastal inundation at the Western RCC (WRCC); agriculture and water resources at the High Plains RCC (HPRCC) and MRCC; water resources and coastal resiliency at the Southern RCC (SRCC); inland/coastal resiliency and human health at the Southeast RCC (SERCC); and resilience to extreme events, along with water resources and critical infrastructure at the NRCC. Based on engagements with local, state, regional, tribal, and national partners and stakeholders in these and other emphasis areas, RCC staff continually become aware of and address emerging climate-related issues. Below, we provide an overview of two tools (the what) that were created to address distinct issues (the why) in different sectors (the who) by producing resources that pair climate data with sector-specific information (the how).

a. Wet-bulb globe temperature tool. **What:** The SERCC worked with NOAA's former Carolinas Integrated Sciences and Assessments team and the North Carolina High School Athletic Association to develop a web-based tool that generates hourly predictions of heat stress, specifically wet-bulb globe temperature (WBGT).

Why: Exposure to extreme heat is the leading cause of weather-related fatalities and is a grave concern for athletic safety. The danger is especially great during the first portion of the fall sports season (e.g., August and early September), as temperature and humidity are still quite high across much of the United States. Also, athletic practices commonly take place in direct sunlight where heat stress is the greatest. Because of the heat danger, an increasing number of state high school athletic associations now require member schools to measure WBGT to determine activity level modifications for football practices.

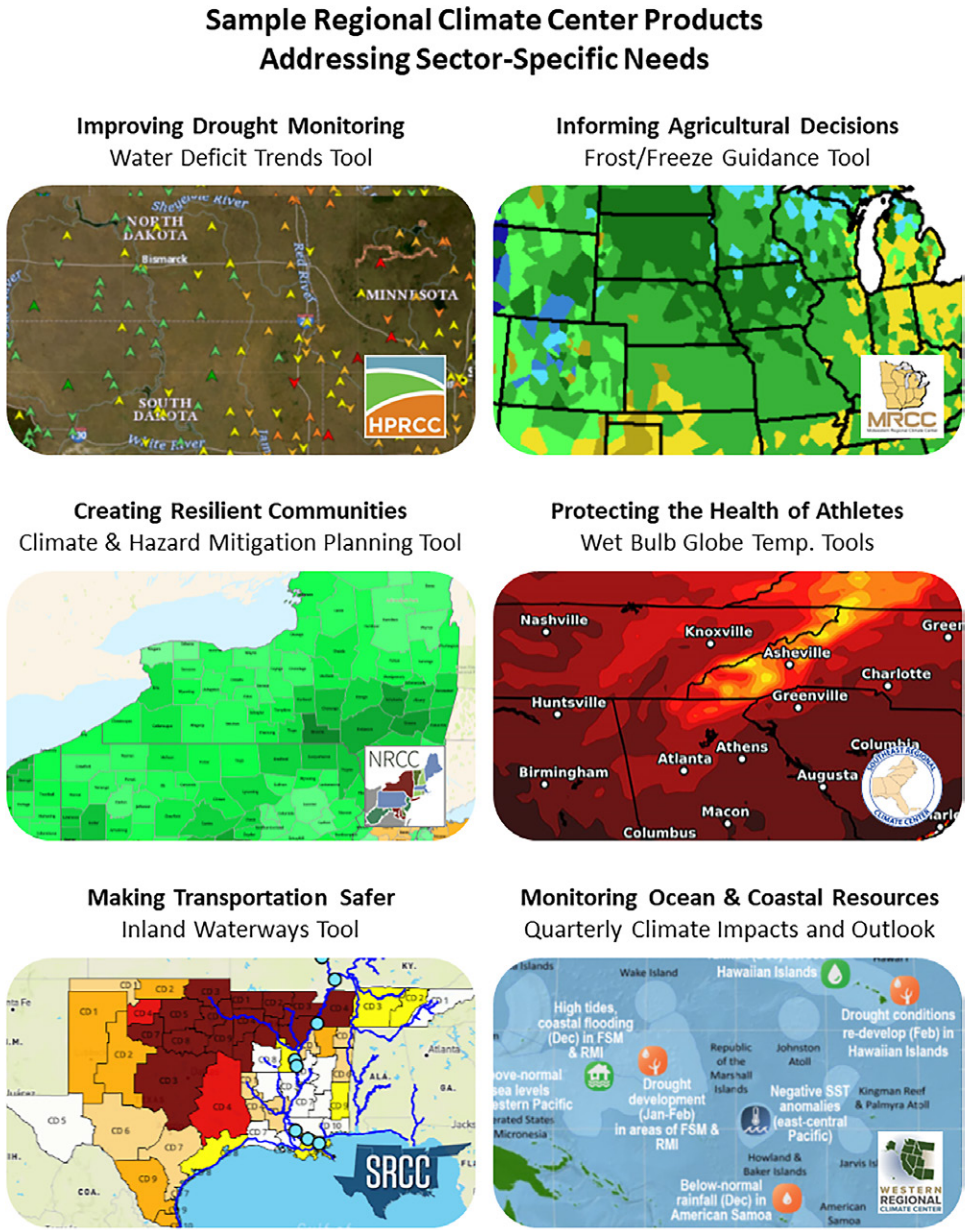

Fig. 3. A collection of RCC products, which address a range of sectoral needs. These include (top left) Water Deficit Trends Tool from the HPRCC (https://hprcc.unl.edu/wdt/), (top right) Frost/Freeze Guidance Tool from the MRCC (https://mrcc.purdue.edu/VIP), (middle left) CHaMP tool from the NRCC (https://champ.rcc-acis.org/), (middle right) WBGT climatology from the SERCC (https://sercc.com/wbgt-climatology/), (bottom left) Inland Waterways Tool from the SRCC (https://www.srcc.tamu.edu/inland_water_drought/), and (bottom right) Quarterly Climate Impacts and Outlook report for the Pacific region from the WRCC (https://wrcc.dri.edu/Climate/Quarterly_Impacts/q_impacts_pac.php).

WBGT is becoming the standard metric for assessing environmental heat stress in the athletic community. It provides a more holistic account of heat stress, as it accounts not only for the effect of air temperature and humidity on human body temperature but also the influence of solar radiation and wind speed. Research at the SERCC reveals that WBGT values on hot days are especially sensitive to small changes in wind speed; for example, a modest drop in wind speed from 3 to 1 mph can increase the amount of heat stress by two flag levels on the five-level scale ranging from no flag (no practice restrictions) to black flag (suspend practice).

Who: Coaches, athletes, or anyone participating in outdoor activities may benefit from using the WBGT tool.

How: The WBGT tool ingests gridded hourly NWS forecasts of temperature, humidity, wind speed, and degree of cloud cover and uses the Liljegren et al. (2008) technique for

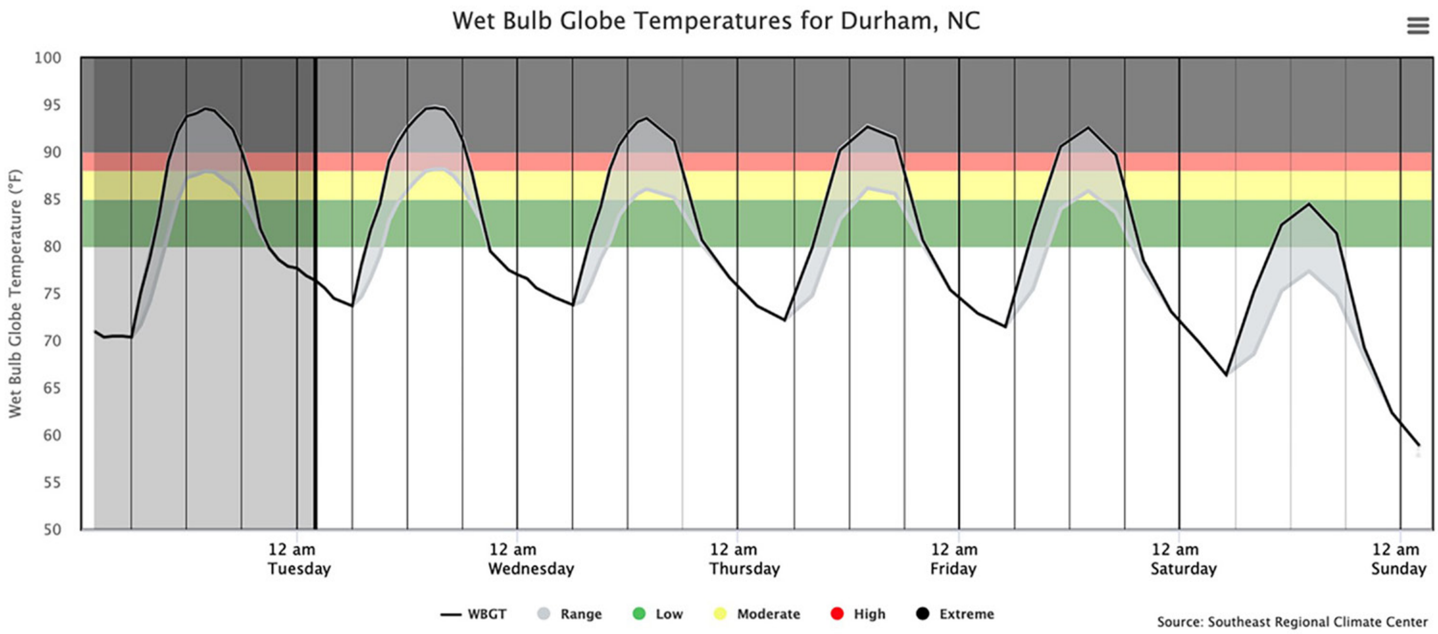

Fig. 4. Example output from the WBGT tool showing a 5-day forecast for Durham, NC.

estimating WBGT. It adjusts this estimate according to the local surface roughness, which is estimated by the degree of tree cover. After choosing their location, users are presented with an interactive graph that shows predicted hourly WBGT values for the next 5 days. In addition, the graph displays the range of forecasted WBGT from conditions of full sun to full shade (Fig. 4). This allows a user to discern how much cooler and safer it would be if practice were held in a shady area.

Where: The WBGT tool and WBGT climatologies may be found online (https://convergence.unc.edu/tools/wbgt/ and https://sercc.com/wbgt-climatology/, respectively).

b. CHaMP tool. **What:** The NRCC hosts the Climate Hazard and Mitigation Planning (CHaMP) tool, which was codeveloped by NOAA's CAP/RISA teams in the mid-Atlantic, Carolinas, and Great Lakes, the Urban Sustainability Directors Network (USDN), and NRCC to provide access to climate data and hazard information specifically to support hazard mitigation planning efforts at multiple levels. Partner and stakeholder input from planners and other practitioners was key to the development and subsequent refinement of the tool.

Why: Communities receiving grant funding from the Federal Emergency Management Agency (FEMA) for disaster mitigation and resilience actions are required to have up-to-date hazard mitigation plans. The hazard mitigation planning process helps communities identify their own local risk to natural disasters and develop strategies to reduce vulnerability to them. CHaMP allows communities to more easily incorporate climate change information into these plans.

Who: Although largely intended for planners of various types—especially those involved in creating hazard mitigation plans—engineers, emergency managers, or any other practitioner in need of data and information related to climate hazards may find this tool to be beneficial.

How: CHaMP integrates historical climate data from Parameter-Elevation Regressions on Independent Slopes Model (PRISM) spatial climate datasets, climate projections from Localized Constructed Analogs (LOCA), and hazard and impact information from the NOAA NCEI Storm Events Database. Access to PRISM and LOCA is provided by ACIS.

Within the CHaMP interface, users can explore state- and county-level climate metrics, hazard data, and hazard impact information based on themes such as extreme rainfall/flooding, extreme heat, tropical storms/hurricanes, and winter weather. Once a theme and

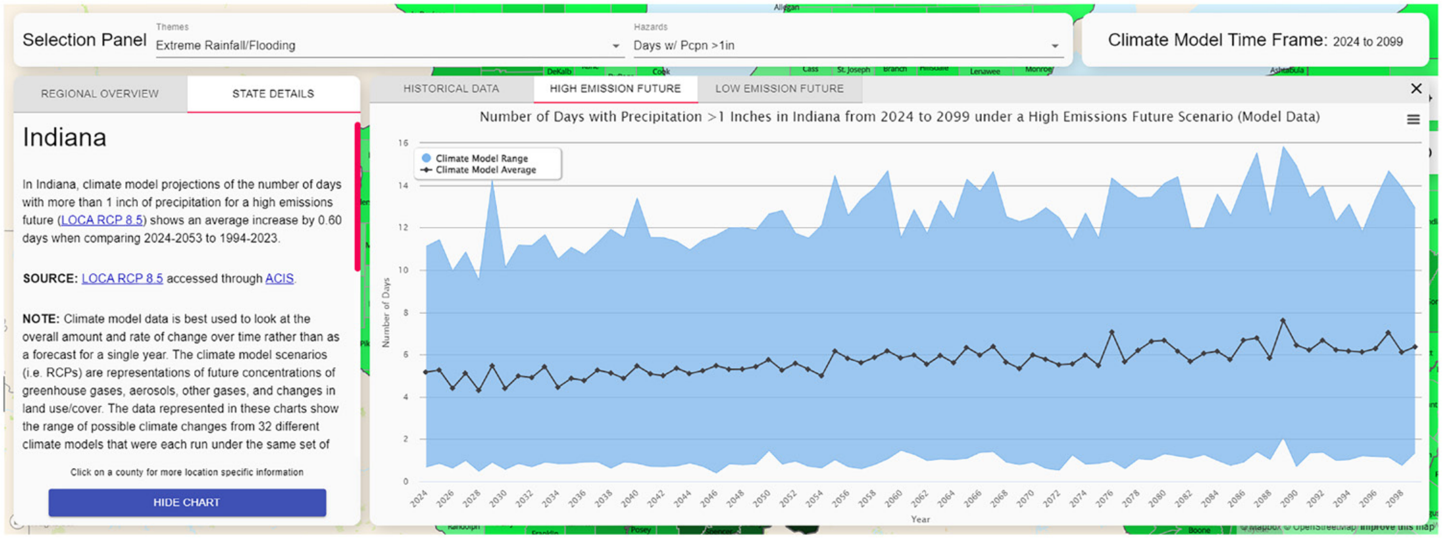

Fig. 5. **Example output from CHaMP displaying state-level precipitation projections under a high emission future for Indiana.**

specific climate metric or hazard are selected, output is presented through maps, graphs, and narratives which summarize data and trends for seamless integration into plans (Fig. 5).

Where: CHaMP may be accessed online (https://champ.rcc-acis.org/).

4. Future of regional climate services

a. The near future. Established RCC activities are anticipated to continue and evolve during the next few years and beyond. In fact, climate services are expected to be a growth area, given the nation's ever-increasing need to adapt to changing climate and extreme events. RCCs have experience in every aspect of climate services, from the collection and quality control of individual observations to the integration of that data into products and services to community and practitioner engagement. By virtue of that experience, the RCCs are poised to tackle—and help other climate service providers tackle—the climate-related challenges of today, the near future, and beyond. Here, we offer two key areas for expansion of RCC services in the near term.

1) Enhancing data and information services. There is an emerging need to build regional capacity for an effective response to increasing weather- and climate-related information needs in all sectors. As observational and model data are key elements in a climate service, increasing ACIS data holdings and capabilities that help support the development of sectoral-based tools will be critical. For example, expanding RCC data holdings/offerings to include in situ data from oceans and coasts, as well as satellite data across the country, would increase the ability to create and provide a more integrated suite of regional weather, water, and climate services. This would be especially important for sectors or communities that have minimal in situ observations, such as large unpopulated areas of the western and mountainous United States or for those seeking elements that typically do not have monitoring stations (e.g., vegetation health or atmospheric moisture). Given the vast amount of climate information that already exists, growth in this area could lead to a potential overload of tools and data for users, so it will be critical to continue to coproduce services with the user community. Acquiring more resources and developing regional public–private–government partnerships could help the RCCs achieve these goals.

2) Enhancing services for frontline communities. The RCC Program is ideally situated for NOAA and other partners to leverage ongoing efforts of engaging more robustly with marginalized and underserved communities in the United States. Specifically, the need to strengthen the capacity for community-based/led monitoring by communities with little to no expertise or resources is vital to begin substantially reducing the equity gap between communities in their ability to respond to climate-related threats. At the same time, communities with moderate to advanced levels of experience and resources also need support to actively monitor climate variables for understanding, at a more granular level, the impact of climate extremes on individuals, families, neighborhoods, rural communities, and communities at risk (such as the unhoused), as well as the health and economic impacts these acute and chronic events have on community resiliency.

Along the same vein, as climate change is increasing exposure to extreme weather events, there is a mounting need to develop climatologies of extreme weather that can be spatially mapped onto geographies of social vulnerability. In many cases, the degree of exposure to a given weather extreme varies across a local scale. For example, vulnerability to falling trees and limbs in a hurricane or severe thunderstorm varies according to the degree and character of tree cover around building structures as well as transportation and utility infrastructure. GIS and remote sensing technologies are currently available to model these variations and produce highly granular datasets (e.g., 10–100-m spatial scale) that can be mapped and overlaid with measures of social vulnerability. Through this approach, a community's overall vulnerability to particular weather hazards can be estimated and compared with other communities. Also, localized variations in vulnerability can be assessed across a community and used to pinpoint where interventions should be focused.

In the near term, the RCCs aspire to work with communities and other climate service providers to build a program focused on community-based/led monitoring and observations that carefully considers the varied level of experience and resources across communities and is designed to actively support reducing the climate equity gap between these communities. The codevelopment of resources that utilize the latest available GIS and remote sensing technologies would be an integral component of this program, and sustained engagement between the RCCs, communities, and other local partners would help support the efficacy of these resources in decision making at the individual level, as well as across organizations and governmental scales.

b. The next 40 years. How might regional climate services change over the next 40 years? Although this will include both human innovation and technological advances, here we primarily focus on the latter—an evolution of technologies that aid climate services over this period of time. Technological discovery and advancement are not linear processes, but instead exponential. Moore's law is one simple example, which states that microchip transistor counts would double every 2 years (Moore 1965). Related to technology, consider the first 40 years of the RCC Program. In the 1980s, when the program was being established, so were desktop computers. Mainframe high-performance computing was not as readily accessible as it is today, and web browsers were not yet a gleam in Tim Berners-Lee's eye (CERN 2023). It would have been difficult to predict in 1983 (the RCC's origin year) what computing capabilities would exist in 2023, especially those in support of regional climate services. Predicting what regional climate services will look like 40 years from now is not without much uncertainty, but there are four technological areas for which we imagine the future: mega-data, quantum computing, artificial intelligence and machine learning, and integrated models and decision making. It is recognized that there will be technological challenges along the way, but below, we offer an optimistic view of how technology might influence regional climate services over the next 40 years.

1) Mega-data. Global climate data collections are immense in storage size, in large part due to radar and satellite data, as well as output from global climate models. As of October 2023, NCEI was retaining 61 petabytes (1 petabyte = 1 quadrillion bytes) of data (N. Ritchey, NOAA/NCEI, 2023, personal communication). NCEI projects that by 2030, the storage demand will be 400 petabytes (NOAA/NCEI 2022). In the program's early years, the RCC's utilized a considerable amount of paper containing typed and handwritten observations that were eventually transcribed into digital storage. For comparison, 1 petabyte is equivalent to 938 249 922 368 pages (1200 characters per page) of plain text (Computer Hope 2020). Significant increases in storage will be needed for increasing volumes of model simulations, forecasts, and projections. Even if storage capacity keeps up with the data, how will all of this climate data get processed, interpreted, and communicated for decision making?

2) Quantum computing. Quantum computers utilize atoms instead of transistors, and the race is on to build these machines (e.g., Kaku 2023). They could revolutionize climate services by providing extensive and readily available computational capacity to allow for problem solving within every aspect of climate and its relation to society. This is not a technological solution to solving climate change, but an evolution coinciding with society's rapid developments in other technologies, especially in regard to climate change mitigation and adaptation efforts. No doubt there are obstacles to overcome in making a quantum computer practical (e.g., Kaku 2023; Tennie and Palmer 2023), but in computing, we have transitioned from analog to digital, and quantum will be the next computer revolution, capable of working on problems unattainable with digital computers. The exponential computing capacity will go hand-in-hand with the exponential storage capacity.

3) Artificial intelligence and machine learning. The use of artificial intelligence (AI) and machine learning (ML) will be a key component of climate service infrastructures. Over the last few years, there has been a rapid increase in the utilization of these tools, so much so that it is now common to see these methods highlighted in climate-related papers and proposals. Given immense amounts of future climate data that will need to be analyzed and distilled for decision making and public consumption, AI and ML will play major roles in this effort as current tools built for digital computing will not be at capacity for quantum computing. We are already discovering relationships in data using ML that, by other methods, would be difficult to resolve. For example, because an important aspect of climate research is pattern recognition, ML is on the cusp of being used to improve the quality of climate datasets through enhanced quality control methods and more efficient inhomogeneity detection. This same technology may also be used to direct potential users to the most suitable climate datasets or tools. Imagine these ML methods in the framework of quantum computing where immense model calculations could be emulated in minutes versus requiring thousands of years on today's fastest supercomputer. It is easy to imagine, even in the very near future, AI managing climate information requests from the public, perhaps even from its own climate services expert voice not unlike current software voice assistants. AI will be capable of assisting decision makers with decision making (Littman et al. 2021). If realized, this will be a very different take on the concept of research-to-operations.

With the revolution in information science and technology, including in AI and ML, climate subject matter experts from a number of disciplines will be in high demand, especially those with communication skills. It will be imperative that these experts are appropriately trained to effectively translate output from new tools and technologies for public consumption.

4) Integrated models and decision making. Of course, climate services 40 years from now will not solely be about technology. Like today, there will be a significant human component in receiving and acting on those services. Warming and associated extreme events continue to increase (NOAA/NCEI 2023), and by mid-century, climate projections suggest many types of extreme events will be much more common, especially given the mid- and higher-range shared socioeconomic and representative concentration pathways. Climate information will be needed for managing shifting ecosystems, changing agricultural practices, human migration, and global interconnected economies.

Even with potential limitations in numerical weather and climate prediction (Tennie and Palmer 2023), quantum computer models could perform countless simulations of scenarios, reduce calculation uncertainties, and factor in a gigantic number of variables in certain new model types. For example, future models could directly compute natural and built environment impacts that are climate driven and not just strictly modeling weather and climate as we know it today. The potential is to have numerical interdisciplinary science models that factor in both physical and social variables and systems such as virtual reality to visualize the output and assist humans with interpretation for decisions, including ways to reduce information overload on practitioners. AI will even be able to improve the model software design. Climate scientists and decision makers 40 years from now will have access to systems and outputs unrecognizable today just as a petabyte of data seemed unrecognizable 40 years ago.

5. Concluding remarks

Forty years ago, regional climate service was a novel concept. Today, there is a public, private, and government expectation of these services in support of all sectors of the economy. Imagine 40 years from now when climate modeling systems are exponentially accruing towards a septillion bytes of climate information output. It is natural to assume that there will be new innovative systems capable of data distillation and visualization corresponding with the data and computational leaps. Climate services will still very much be essential in the future as society lives and conducts its business within Earth's sphere of climate. We encourage the next generation of applied climate scientists and service providers to embrace this challenge and create new ways to bridge the ever-growing gap between raw data and actionable climate information, much like the RCCs have done over the last 40 years.

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References

CERN, 2023: The birth of the Web. Accessed 13 September 2023, https://home.cern/science/computing/birth-web.

Changnon, S. A., P. J. Lamb, and K. G. Hubbard, 1990: Regional climate centers: New institutions for climate services and climate-impact research. *Bull. Amer. Meteor. Soc.*, **71**, 527–537, https://doi.org/10.1175/1520-0477(1990)071<0527:RCCNIF>2.0.CO;2.

Computer Hope, 2020: How much is 1 byte, kilobyte, megabyte, gigabyte, etc.? Accessed 13 September 2023, https://www.computerhope.com/issues/chspace.htm.

DeGaetano, A. T., T. J. Brown, S. D. Hilberg, K. Redmond, K. Robbins, P. Robinson, M. Shulski, and M. McGuirk, 2010: Toward regional climate services. *Bull. Amer. Meteor. Soc.*, **91**, 1633–1644, https://doi.org/10.1175/2010BAMS2936.1.

Kaku, M., 2023: *Quantum Supremacy: How the Quantum Computer Revolution Will Change Everything.* 1st ed. Knopf Doubleday Publishing Group, 352 pp.

Kunkel, K. E., S. A. Changnon, C. G. Lonnquist, and J. R. Angel, 1990: A real-time climate information system for the Midwestern United States. *Bull. Amer. Meteor. Soc.*, **71**, 1601–1609, https://doi.org/10.1175/1520-0477(1990)071<1601:ARTCIS>2.0.CO;2.

——, and Coauthors, 1998: An expanded digital daily database for climatic resources applications in the Midwestern United States. *Bull. Amer. Meteor. Soc.*, **79**, 1357–1366, https://doi.org/10.1175/1520-0477(1998)079<1357:AEDDDF>2.0.CO;2.

Liljegren, J. C., R. A. Carhart, P. Lawday, S. Tschopp, and R. Sharp, 2008: Modeling the wet bulb globe temperature using standard meteorological measurements. *J. Occup. Environ. Hyg.*, **5**, 645–655, https://doi.org/10.1080/15459620802310770.

Littman, M. L., and Coauthors, 2021: Gathering strength, gathering storms: The one hundred year study on artificial intelligence (AI100) 2021 study panel report. arXiv, 2210.15767v1, https://doi.org/10.48550/arXiv.2210.15767.

Mahmood, R., and Coauthors, 2017: Mesonets: Mesoscale weather and climate observations for the United States. *Bull. Amer. Meteor. Soc.*, **98**, 1349–1361, https://doi.org/10.1175/BAMS-D-15-00258.1.

Moore, G. E., 1965: Cramming more components onto integrated circuits. *Electronics*, **38**, 114–117.

NOAA/NCEI, 2022: NCEI archive: Growth and change. Accessed 13 September 2023, https://www.ncei.noaa.gov/news/ncei-archive-growth-and-change.

——, 2023: U.S. billion-dollar weather and climate disasters. Accessed 13 September 2023, https://www.ncei.noaa.gov/access/billions/.

Tennie, F., and T. N. Palmer, 2023: Quantum computers for weather and climate prediction: The good, the bad, and the noisy. *Bull. Amer. Meteor. Soc.*, **104**, E488–E500, https://doi.org/10.1175/BAMS-D-22-0031.1.