

From NOAA Data to Heat-Safety Decisions: The Evolution and Value of the SERCC's Wet Bulb Globe Temperature Prediction Tool

On a hot summer afternoon, a coach preparing for football practice faces a deceptively simple question: Is it safe to practice outside? The answer cannot be found in air temperature alone. A 90 degree F afternoon beneath cloud cover with a steady breeze can feel very different from the same temperature under intense sunshine with little wind. Lots of things matter when it comes to human thermal comfort, including humidity, solar radiation, the surrounding landscape, and the amount of physical exertion involved. The characteristics of the people being exposed matter as well.

These types of decisions play out every day when it gets hot. A construction supervisor may need to determine when and how often workers should take rest breaks. A school administrator may have to decide whether students should go outside for recess. Athletic trainers and coaches may alter practice schedules. Emergency managers and public health officials may need to determine when additional resources or public messaging are warranted. Today, all of them have access to large amounts of weather data. But data alone do not answer the question they are being asked to answer: What should we do?

That distinction, between having more data and having *information that supports a decision*, has driven nearly two decades of heat-related research and climate services at the SERCC. One of the most important products to emerge from that work is the [Wet Bulb Globe Temperature \(WBGT\) Prediction Tool](#). Built upon NOAA-managed weather data and years of applied research and engagement with the people who make heat-related decisions, the tool translates weather forecasts into actionable guidance around heat stress across much of the country, including the U.S. Caribbean. The evolution of the tool also illustrates a broader lesson about the value of NOAA's weather and climate services: *It is not just about data, it is about decisions based on actionable information.*

Extreme heat is a particularly challenging hazard because the conditions people experience can vary considerably over short distances and periods of time. Regional weather conditions provide the backdrop, but exposure also depends on the immediate environment. Shade, direct sunlight, wind, surface type, vegetation, buildings, and other features can influence the heat stress experienced by someone working, exercising, or simply spending time outdoors. Traditional weather forecasts provide information about temperature, humidity, wind, cloud cover, and other atmospheric conditions. Yet decision makers often need a way to bring these variables together and translate them into an indication of the potential stress placed on the human body. For decades, the heat index has been the most familiar way of communicating dangerous heat by combining air temperature and humidity to describe how hot conditions feel. But many outdoor activities occur in environments where other factors, particularly solar radiation and wind, can substantially affect heat stress. WBGT offers a better perspective by combining temperature, moisture, solar radiation, and wind to characterize environmental heat stress (Figure 1). Because it incorporates several of the factors that influence the body's ability to maintain a safe

core temperature, WBGT has long been used in settings where people engage in strenuous outdoor activity, including athletics, military training, and outdoor work.

	Air Temperature	Heat Index	Wet Bulb Globe Temperature (WBGT)
Measured in the sun?			✓
Includes air temperature?	✓	✓	✓
Includes relative humidity?		✓	✓
Includes wind?			✓
Includes cloud cover?			✓
Includes sun angle?			✓

Figure 1. A comparison of commonly used heat metrics (adopted from the North Carolina State Climate Office [Extreme Heat Dashboard](#)).

Just as importantly, WBGT can be paired with established activity guidelines so that, rather than simply telling a coach or worker that conditions are hot, it can place those conditions into categories associated with recommended changes in activity, rest, hydration, equipment, or exposure (Figure 2).

WBGT Activity Guidelines and Rest/Break Guidelines for Athletes		
Heat Category	WBGT Index (F)	Activity Guidelines
No Flag	Under 80	Unlimited activity with primary cautions for new or unconditioned athletes or extreme exertion; schedule mandatory rest/water breaks. (5 min rest/water break every 30 min)
Low (Green Flag)	80-84.9	Normal practice for athletes; closely monitor new or unconditioned athletes and all athletes during extreme exertion. Schedule mandatory rest/water breaks. (5 min water/rest break every 25 min)
Moderate (Yellow Flag)	85-87.9	New or unconditioned athletes should have reduced intensity practice and modifications in clothing. Well-conditioned athletes should have more frequent rest breaks and hydration as well as cautious monitoring for symptoms of heat illness. Schedule frequent mandatory rest/water breaks. (5 min rest/water break every 20 min) Have cold or ice immersion pool on site for practice.
High (Red Flag)	88-89.9	All athletes must be under constant observation and supervision. Remove pads and equipment. Schedule frequent mandatory rest/water breaks. (5 min rest/water break every 15 min) Have cold or ice immersion pool on site for practice.
Extreme (Black Flag)	Over 90	SUSPEND PRACTICE

Figure 2. WBGT flag categories and activity guidelines from the NC High School Athletics Association. It is important to note that guidelines and WBGT thresholds differ among organizations and locations.

This ability to connect environmental conditions with potential actions is what makes WBGT particularly useful as a decision-support metric. However, WBGT is considerably more complicated to measure and predict than air temperature or even heat index. This challenge

would eventually become an opportunity for the SERCC. The WBGT Prediction Tool grew from a much longer history of work at the intersection of weather, climate, and human health. In 2009, the SERCC co-hosted a workshop at NCEI addressing information gaps between the climate and health communities, helping establish what has become a sustained program of heat-health research and engagement. Over the following years, collaborations with public-health researchers, state and federal agencies, NOAA partners, and UNC colleagues examined relationships among weather, heat exposure, vulnerability, and human health. That work produced peer-reviewed research, stakeholder engagement, and decision-support tools, and eventually raised a new question: Could heat information better reflect the conditions people actually experience outdoors?

WBGT offered a promising answer. NOAA already maintained much of the observing, forecasting, and scientific infrastructure needed to obtain the data. The opportunity for the SERCC was to add a layer of value by translating those data into information tailored to a specific decision. That process can be thought of as a value chain (Figure 3):

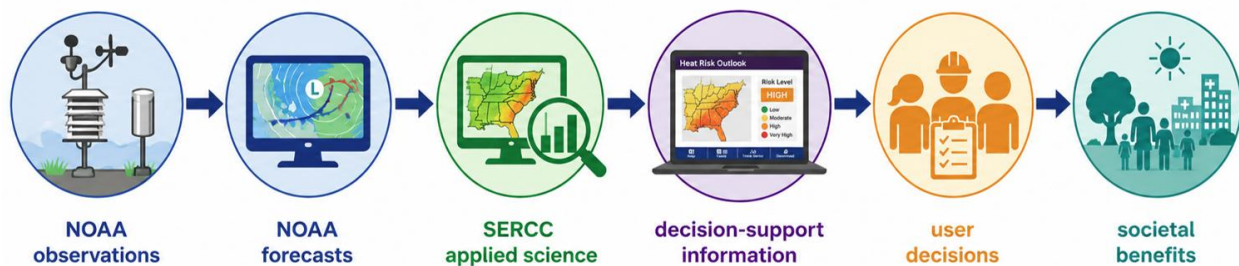


Figure 3. Value chain representing the process of translating NOAA data into tools and products that help users make decisions for societal benefit.

At each step, the information becomes more directly connected to an action. A weather observation has value, and a forecast based on those observations has additional value. But for a coach trying to decide whether to modify practice, the greatest value may come when those forecasts are translated into an expected WBGT category tied to specific activity guidance. That became the vision behind the WBGT Prediction Tool.

The idea behind the tool was straightforward. If WBGT could help determine whether conditions were safe for outdoor activity, could that information be provided *before* people went outside? At the time, that was not an easy question to answer. Although WBGT had been used for decades by the military and was increasingly being adopted in athletics and occupational settings, routinely available WBGT forecasts were (and still are) uncommon. That meant WBGT was primarily useful for assessing conditions as they were happening. A coach could take a WBGT meter onto an athletic field, for example, but that measurement could not tell the coach what conditions would be like at tomorrow afternoon's practice. Working with the Carolinas Integrated Sciences and Assessments (CISA) program, the SERCC began developing a way to transform existing NOAA data and weather forecasts into predictions of WBGT. The first version of the tool was developed in 2018 and became operational during the summer of 2019. Rather than create a new observing or forecasting system, SERCC built upon NOAA's existing

infrastructure, combining NWS forecasts of temperature, humidity, wind, clouds, and other atmospheric conditions with a physically based method for estimating WBGT. The result is a five-day forecast of hourly heat stress.

Unlike the heat index, WBGT is not scaled to feel like an equivalent air temperature, so the numerical values can be misleading. For this reason, heat risk is typically communicated using color-coded flag levels rather than the WBGT values themselves. WBGT values correspond to different levels of heat danger, represented as green, yellow, red, and black "flags" that can be connected directly with guidelines for modifying activity (see Figure 2). A forecast therefore turns a measurement into advance notice. Instead of discovering at 3pm that conditions have reached black flag, an athletic director or coach can see the possibility the day before and begin considering whether practice should start earlier, move to another location, or be modified. An outdoor supervisor can anticipate when additional rest may be required. Advance information creates additional options, and that is a major step in the tool's value chain.

The idea for the WBGT Prediction Tool did not begin with an algorithm. It began with conversations. Through a long-standing partnership with the North Carolina High School Athletic Association (NCHSAA), SERCC and CISA researchers worked directly with athletic trainers, coaches, and athletic directors to understand how heat affected decisions on the ground. SERCC Director Dr. Chip Konrad, who became the NCHSAA's inaugural Sports Medicine Consultant in 2015, helped bridge the weather and athletic communities, with a particular focus on heat-illness prevention and safe outdoor activity. An early visit with an athletic trainer at Cedar Ridge High School in Hillsborough, NC helped researchers see the problem firsthand. An estimate of WBGT from a nearby weather station might not represent the conditions athletes were actually experiencing on their own field. If WBGT was going to guide decisions, users needed information that better reflected where activities were taking place, and they needed it before practice began.

Those conversations continued as the tool became operational. From 2020 to 2021, SERCC visited high schools from Bryson City in the mountains to Wilmington on the coast, encountering differences in shade and exposure as well as very different logistical constraints. Some schools could easily move practice to a cooler time of the day and others had little flexibility because of transportation, facilities, or other demands. The lesson was simple: useful heat information had to account not only for the weather, but also for the decisions users actually had the ability to make. CISA's sustained relationships with these communities helped keep that user perspective connected to the science as the tool evolved. That engagement extended beyond development of the forecast itself. Beginning around 2021, SERCC and CISA collaborated with Dana Haine from UNC's Institute for the Environment to introduce high school teachers and students to extreme heat, WBGT, and the environmental factors that shape heat stress. And in 2022, the North Carolina Athletic Trainers' Association (NCATA) recognized Dr. Konrad with its [President's Award](#) for the SERCC's work supporting student-athletes and athletic trainers (Figure 4).



Figure 4. SERCC Director Dr. Chip Konrad receiving the NCATA President's Award in 2022. The association noted that he sought "to learn from our profession as much as to educate", affirming the approach that helped give rise to the WBGT Prediction Tool.

Launching the WBGT Prediction Tool was not the end of its development. As more people used the tool, new questions emerged. Those questions and the research needed to answer them have driven its evolution ever since. Below are some notable examples:

Can the tool be used outside the Carolinas?

The original version of the tool only covered the Carolinas, but interest in WBGT was growing elsewhere. In 2021, the tool expanded to the Southeast region, and in April 2022, the tool expanded to the eastern two-thirds of the contiguous U.S. (Figure 5). At about the same time, the SERCC began assembling activity guidelines associated with different WBGT flag levels (Figure 5). This was an important addition because WBGT thresholds and recommended actions are not identical for every population or organization. A high school athlete wearing protective equipment does not necessarily have the same guidelines as a worker performing another type of outdoor activity. Rather than prescribe a single set of thresholds, the tool increasingly became a gateway through which users could access guidance appropriate to their circumstances.

That collection continues to evolve as organizations revise their heat-safety policies. Most recently, the Texas University Interscholastic League (UIL) made its WBGT-based heat safety guidelines mandatory for all outdoor athletic practices, following several years in which the guidelines were recommended but not required. Under the [new policy](#), which went into effect on August 1, 2026, schools must monitor WBGT shortly before and throughout outdoor practices

and modify activities as heat exposure increases, including providing additional rest and cooling opportunities, limiting protective equipment and practice duration, and ultimately suspending outdoor practice when WBGT exceeds established thresholds. The requirements vary geographically to account for differences in heat acclimatization across Texas and are intended to establish a consistent, science-based standard for protecting student-athletes from exertional heat illness. The change also makes reliable, location-specific WBGT information increasingly important for coaches and athletic trainers, since WBGT conditions can now directly determine when, how long, and under what conditions teams are permitted to practice.

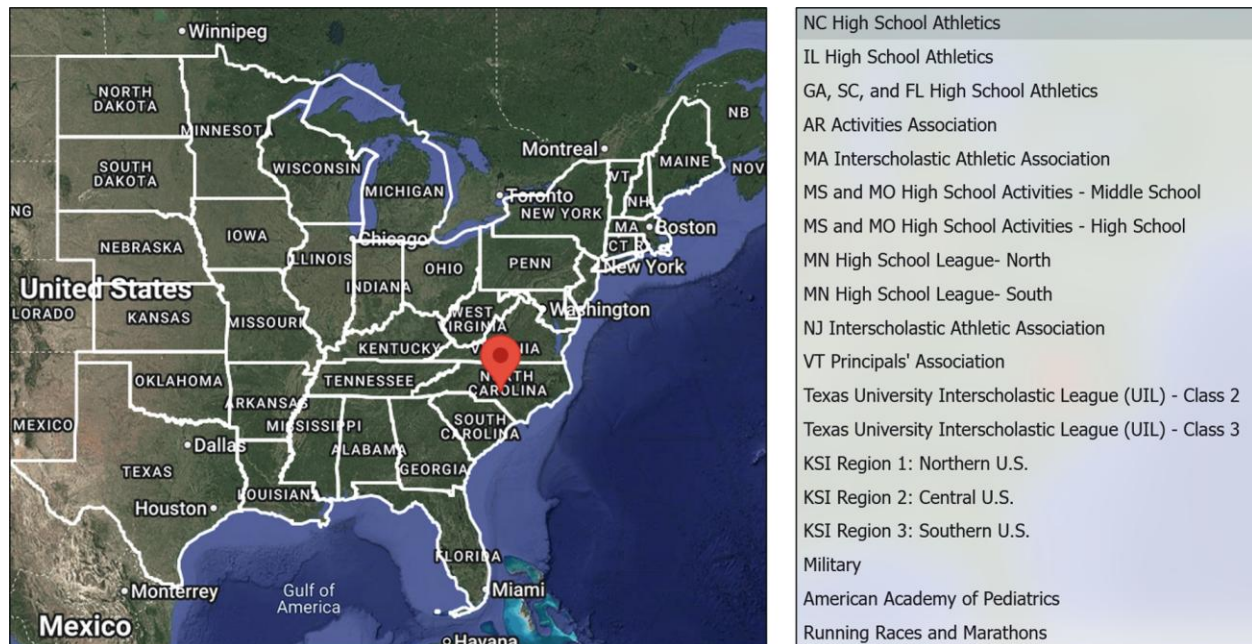


Figure 5. Map showing the geographic coverage of the tool across the contiguous U.S. (left); list of available flag level guidelines, as of August 2026 (right).

What about conditions in the sun and shade?

Field observations demonstrated that sun and shade could produce meaningfully different WBGT conditions. That evidence supported an important evolution of the tool by helping users consider both environments. For someone responsible for outdoor activity, this creates another potential intervention. Cancelling an activity is not always the only option; moving it into shade or scheduling activity during a period with less direct solar exposure may meaningfully reduce environmental heat stress (Figure 6).

Why can two nearby places feel so different?

The answer to that question became increasingly apparent as SERCC researchers took WBGT instruments into the field. WBGT can change substantially over remarkably small distances because the factors determining heat stress, particularly radiation and wind, are themselves strongly influenced by the local environment. A paved tennis court and neighboring grassy field, for example, do not interact with solar energy in the same way. Field work conducted by Jordan Clark, then a PhD student and research assistant with the SERCC, found WBGT over tennis

courts averaged approximately 2 degrees F warmer than over neighboring grass, with differences large enough in some circumstances to place the two locations in different WBGT categories. Sun versus shade produced even larger contrasts. Wind presented another important challenge, as trees and buildings slow the wind near the surface. Because even modest air movement helps remove heat from our bodies, small changes in wind can produce surprisingly large changes in WBGT. One example from Jordan's research illustrates just how consequential that can be. Under otherwise identical sunny conditions, decreasing the wind from 3 to 1 mph can increase WBGT by two flag categories (Figure 7). In other words, the difference between an open athletic field and a sheltered area surrounded by trees or buildings can sometimes be the difference between conditions requiring modest activity modifications and conditions requiring much more significant action. That presented SERCC with another question: Could the forecast better account for the landscape itself?

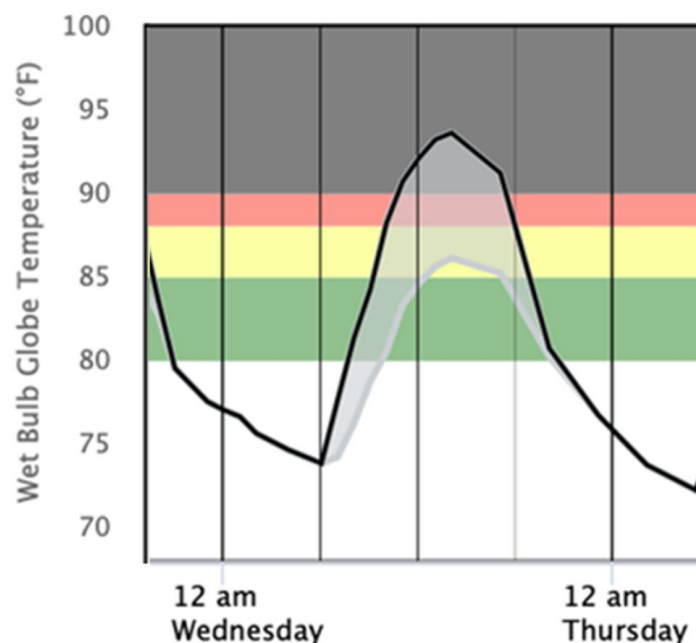


Figure 6. Example of a WBGT Prediction Tool forecast chart showing the forecast WBGT by hour over a 24 hour period (solid black line); colored areas represent flag level conditions based on the guidelines shown in Figure 2; the gray shaded area below the black line shows the range in WBGT from full sun at the top, which puts the forecast WBGT in black flag, to full shade at the bottom (thick gray line), which lowers the forecast WBGT to yellow flag.

Making the forecast more “local”

Weather forecasts typically provide wind information for the general environment experienced by an individual. But the wind felt by an athlete or outdoor worker near the ground is influenced by trees, buildings, and other obstacles. SERCC researchers therefore explored whether satellite-derived information about vegetation and land cover could be used to better estimate how much the surrounding landscape slows the wind. The approach considers landscape “roughness” across multiple scales, from the immediate surroundings out to several hundred meters, and uses that information to translate forecast wind speeds to the scale at which people

actually experience them. The result was a 5-fold increase in the spatial resolution of the forecast from 2.5 kilometers to 500 meters (about 1.5 to 0.3 miles). This improvement proved particularly useful in sheltered environments, such as areas with substantial tree cover or large buildings, showing what applied research looks like in practice.

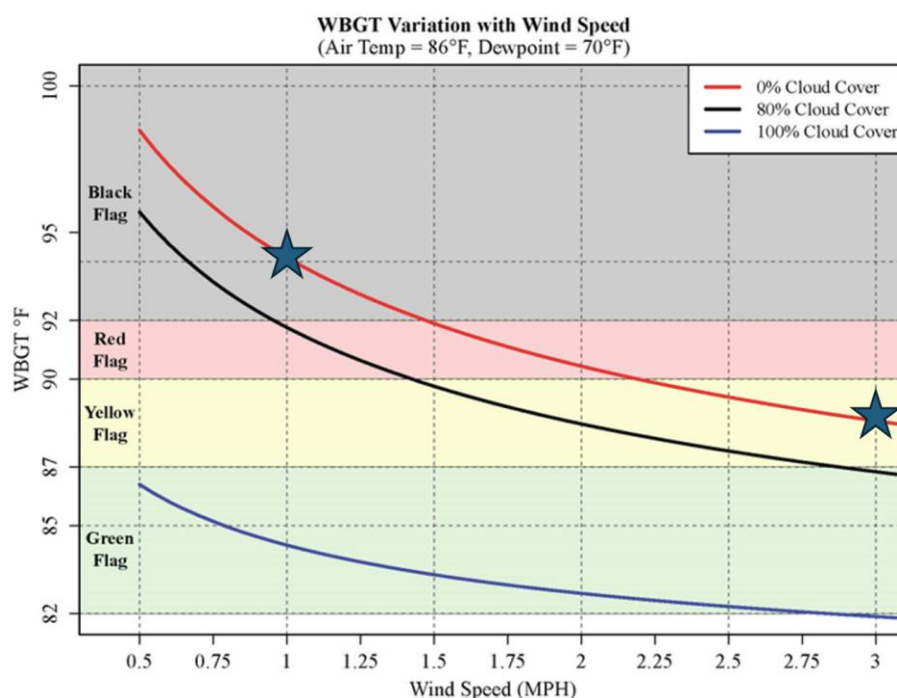


Figure 7. Relationship between WGBT and wind speed depicted for three categories of cloud cover with an air temperature of 86 degrees F and a dewpoint of 70 degrees F. Adopted from Figure 1 in Clark and Konrad (2024).

Can it work in the Caribbean?

Another question emerged following the extraordinary heat experienced across the U.S. Caribbean in 2023: Could the same approach work in Puerto Rico and the U.S. Virgin Islands? NOAA partners and regional stakeholders were looking for heat information that could better reflect the conditions people actually experience across the islands. In early 2024, the WGBT Prediction Tool expanded to cover the region, including the outlying islands. That same year, the SERCC participated in the inaugural [U.S. Caribbean Extreme Heat Summit](#), where staff demonstrated the tool directly to regional partners (Figure 8). Participants raised questions that reflected the unique challenges of applying heat information across the Caribbean. Could forecasts better account for Puerto Rico's dramatic changes in elevation? Could vegetation, pavement, and other features of the landscape help explain local differences in heat? Could forecasts become more granular, eventually approaching the scale of individual communities? And as WGBT reached new audiences, how could guidance better reflect the needs of particular populations, from farmers to people especially vulnerable to heat?



Figure 8: SERCC Deputy Director Dr. Chris Fuhrmann demonstrating the WBGT Prediction Tool to participants at the inaugural U.S. Caribbean Heat Summit in 2024. The event was hosted by the Caribbean Climate Adaptation Network (CCAN), the region's RISA program.

Those conversations continued. During a May 2026 meeting of the Caribbean Climate Adaptation Network (CCAN), discussion increasingly focused on children, a particularly vulnerable population. Regional partners identified a need for high-resolution, impact-based information that could better reflect conditions at schools and childcare facilities, where shade, vegetation, development, sea breezes, and other local features can shape heat exposure. Participants also identified American Academy of Pediatrics WBGT flag-level guidance as a useful starting point for communicating risk. What began as a question about extending an existing forecast to the Caribbean has therefore become something larger: How can the tool better reflect the places and people it is intended to serve? The answers are helping move SERCC's work toward increasingly localized heat information and creating new opportunities to connect NOAA data with public health, education, and community resilience planning across the U.S. Caribbean.

A forecast map can be visually compelling, but for someone responsible for the health of athletes, workers, students, or communities, appearance is not enough. They need to trust it, and that trust is built through science. From 2019 to 2021, SERCC researchers took WBGT instruments into athletic, suburban, rural, and urban environments across the Carolinas (Figure 9). Rather than assuming that the forecast worked, they compared predictions with what people were actually experiencing on the ground. The results provided strong evidence that WBGT can be successfully forecast. Across the North Carolina observations that were published in the journal *Weather and Forecasting*, SERCC's forecast was within approximately 1 degree F of observed WBGT on average ([Clark et al. 2024](#)). Importantly, it performed especially well during

the highest and most dangerous WBGT values, conditions that matter most for heat safety. And that's important, because a forecast that performs well on pleasant summer mornings but systematically misses the most dangerous afternoons would have limited value as a health-protection tool. The evaluation instead showed that the SERCC approach was particularly capable of identifying dangerous conditions.



Figure 9. Examples of SERCC field work utilizing WBGT meters and meteorological equipment across various locations in the Carolinas.

The research also revealed an unavoidable tradeoff. The forecast tended to err toward predicting dangerous red and black flag conditions more often, producing some false alarms. But it was less likely to miss dangerous conditions. For a decision-support tool designed to protect health, that distinction is meaningful. A false alarm can lead to an unnecessary schedule change. Failing to anticipate dangerous heat can expose people to conditions for which they were not prepared. This does not mean forecasts should replace measurements at the site of an activity. Quite the opposite. This research emphasizes that real-time, on-site measurements remain important precisely because WBGT is so sensitive to microclimatic conditions. The two sources of information serve different purposes. The forecast helps people plan, while the observation helps them make the final decision. That distinction may be one of the most useful messages that can be communicated to users.

Learning from the landscape

The validation research also helped explain where some of the forecast uncertainty comes from. Among the most important factors is wind. Weather forecasts typically describe wind over spatial scales much larger than an athletic field, construction site, schoolyard, or city block. Yet trees and buildings can substantially reduce wind near the ground. Incorporating satellite-derived information about surface roughness improved the WBGT forecast, particularly at more sheltered sites. Radiation presented another challenge. Most routine weather stations do not directly measure all of the information needed to calculate WBGT. SERCC research therefore evaluated several ways of estimating clear-sky radiation and adjusting those estimates for

clouds, identifying methods that substantially improved the representation of the radiative environment ([Clark and Konrad 2024](#)).

Field research simultaneously revealed why these refinements matter. WBGT varied significantly between sun and shade and between different surfaces. Even a commonly used handheld WBGT instrument showed a measurable warm bias compared with an instrument meeting international measurement standards ([Clark and Konrad 2024](#)). The lesson was not that WBGT is unreliable. It was that heat exposure is genuinely local. The human body responds to the conditions where a person is standing, not to the average conditions across a 2.5 km forecast grid. That realization is now driving the next stage of the SERCC's work.

From regional forecasts to neighborhood “fingerprints”

Current and future research is combining citizen-science heat mapping with machine learning to understand how WBGT responds to land-cover characteristics at extremely fine scales ([Robinson et al. 2026](#)). Rather than attempting to place a weather station on every street, researchers can collect large numbers of observations across an urban area and identify relationships between WBGT and features such as vegetation, development, shade, and the openness of the surrounding landscape. Those relationships can then be used to create heat “fingerprints” of communities at scales down to just 10 meters, or 33 feet (Figure 10).

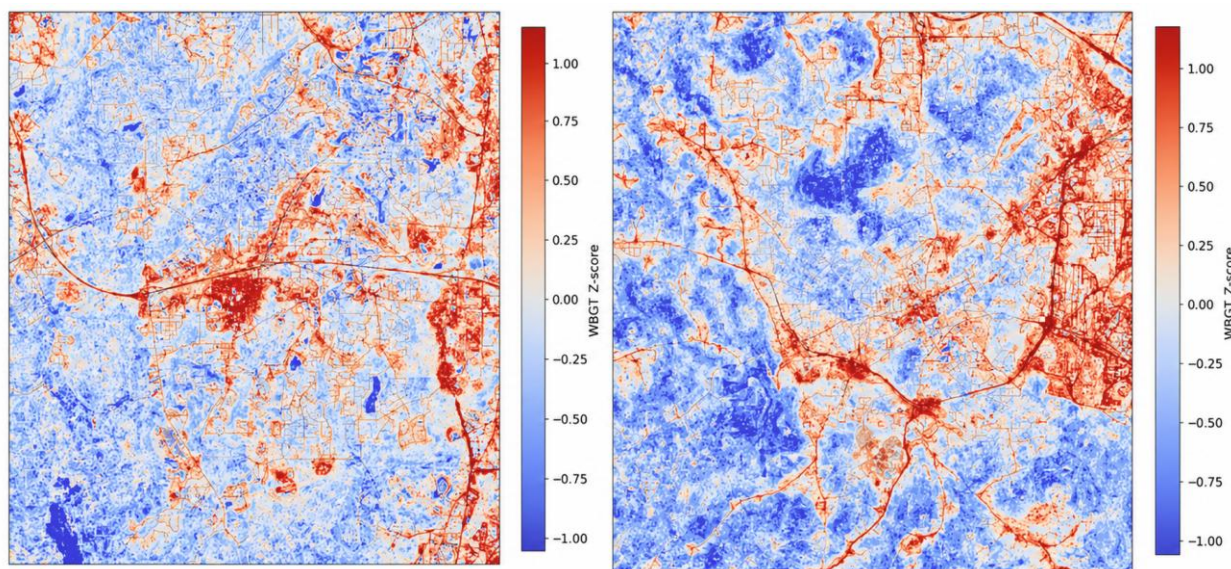


Figure 10. Spatial distribution of WBGT at 10 meter resolution across South Durham (left) and Chapel Hill in central North Carolina using data collected from mobile transects and machine learning techniques described in Robinson et al. (2026). Areas with high WBGT are shown in red, while areas with lower WBGT are shown in blue.

The long-term objective is to connect those neighborhood fingerprints with the coarser WBGT Prediction Tool, allowing a NOAA forecast to be progressively translated from the regional scale to the neighborhood scale. The evolution therefore continues, moving from regional WBGT forecasts and guidance to neighborhood heat exposure informed by local landscape features,

leading to better local decision-making. What began nearly a decade ago as a forecast covering the Carolinas is increasingly becoming an experiment in how far weather information can be translated toward the scale at which people actually experience heat. And that is ultimately the scale at which decisions are most relevant.

A tool creates little societal value if nobody uses it. Since its launch, the WBGT Prediction Tool has grown from select users in the Carolinas to a resource accessed by users from across the U.S., including Puerto Rico and the Virgin Islands. Website analytics provide one measure of that growth (Figure 11). Since analytics became available in April 2022, use of the tool has closely followed the seasonal need for heat information. Website views typically begin increasing during the spring, rise sharply during June and July, and peak during the hottest part of summer before declining again in the fall. The magnitude of those summer peaks, however, has changed as the tool has expanded and new guidance has been added. In June 2022, the forecast expanded to cover the eastern two-thirds of the contiguous U.S. and a menu of WBGT flag-level guidelines was added to help users connect forecast conditions with recommended actions. Coverage expanded again in February 2024 to include Puerto Rico and the U.S. Virgin Islands. Coverage expanded again in February 2024 to include Puerto Rico and the U.S. Virgin Islands.

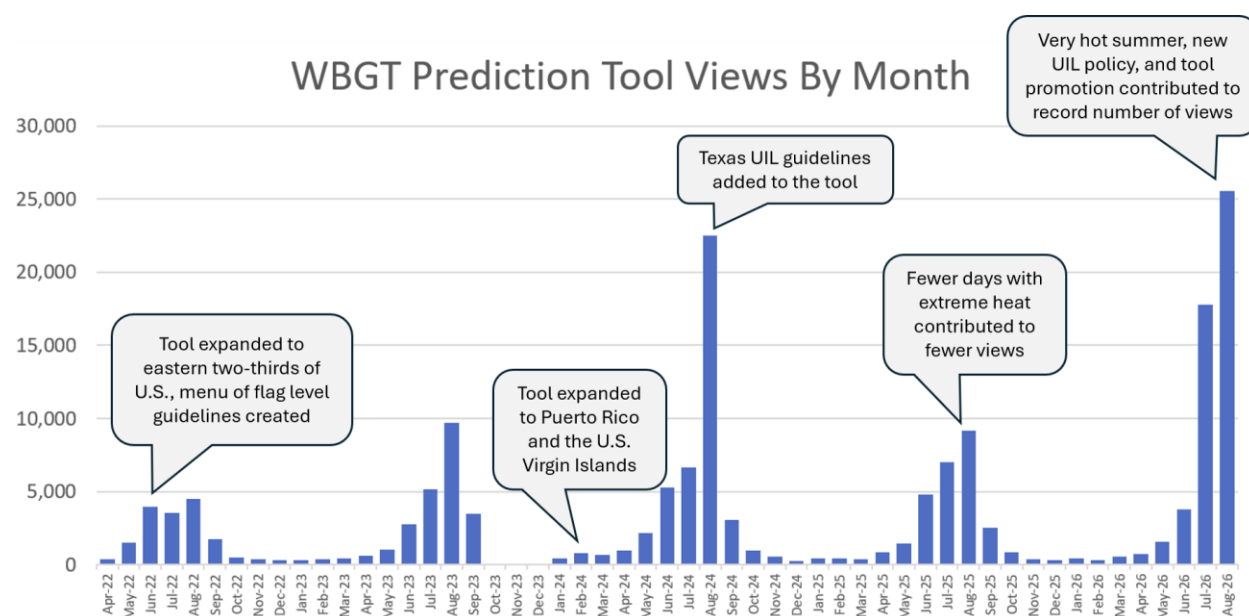


Figure 11. Monthly WBGT Prediction Tool views from April 2022 through August 24, 2026.

Weather also influences when people seek out the tool. The hot summer of 2024 coincided with a sharp increase in use, with 34,477 views recorded from June through August. Views declined during the comparatively cooler summer of 2025, particularly during August, before surging again amid the hotter conditions of 2026. From June through August 24, 2026, the tool recorded 47,098 views, more than twice the number recorded during the same summer months in 2025. August 2026 alone has already generated 25,528 views, the highest monthly total in the available record, with a week still remaining in the month. This pattern suggests that the tool's

audience has grown over time, while engagement is greatest when the need for heat-safety information is most immediate.

Perhaps the clearest example of how tailoring the tool to user needs can expand its reach comes from Texas. At the request of the Texas UIL, the SERCC added Texas-specific WBGT activity guidelines to the tool in May 2024. As schools prepared for fall athletics that summer, use increased sharply, with views from Texas rising from 2,173 in July to 13,755 in August. The hot summer likely contributed to that increase, illustrating how product relevance and weather-driven demand can work together. Usage moderated during the cooler summer of 2025 but surged again in 2026 as new UIL heat-safety requirements took effect. Since June 2026, Texas alone has generated 31,112 views, most of these from the Dallas area, providing a striking example of how decision-specific guidance can connect NOAA information with a large and growing community of users.

From forecast to statewide practice

The growth in Texas is more than a web-traffic story. As the UIL updated its heat-safety plan in 2024, Athletic Director Ray Zepeda and his colleagues became aware of the SERCC tool and included a link to it so coaches could better understand the conditions they might encounter in the coming week. When UIL subsequently moved from recommending its WBGT-based heat plan to requiring it statewide, the tool remained prominently linked within the plan. Zepeda says UIL has even used the forecast when reviewing reports of potential noncompliance, providing another source of information about the conditions expected at a particular place and time. For Zepeda, the value of prediction is not that it replaces the measurements schools are required to take at the field. Instead, the two pieces of information serve different purposes:

“Forecast WBGT information adds another important layer because it allows schools to be proactive rather than simply reactive.”

A forecast can give schools time to adjust practice schedules, prepare hydration and cooling resources, modify equipment or practice plans, and make sure coaches and athletic trainers know what conditions they are likely to encounter. The on-site measurement then determines what modifications are required when athletes actually take the field.

The connection has extended through NOAA as well. With WBGT now required for Texas UIL outdoor athletic and marching-band activities, the NWS Austin/San Antonio office has received requests from schools, health officials, and emergency managers for resources that can help them anticipate WBGT conditions. According to Warning Coordination Meteorologist Jason Runyen, ***“We have found tools that display NWS WBGT forecasts overlaid on top of the new UIL requirements to be highly effective. Specifically, the WBGT Tool, developed by the Southeast Regional Climate Center, provides this information in an easy-to-understand format, and is a resource we have already shared with over 2,000 partners. Tools like this complement our heat messaging and the alerts we issue at the NWS.”***

Reaching new audiences

The growing use of WBGT is also introducing the metric to entirely new audiences. In August 2026, SERCC received an inquiry from a Texas parent whose five-year-old son's baseball league had begun using WBGT to determine whether practices should be cancelled. The parent had never encountered WBGT before and contacted the SERCC seeking help understanding how the information should be applied to young children. This illustrates both the expanding reach of WBGT-based decision making and an emerging challenge: as WBGT moves beyond military, occupational, and high-school athletic settings, users increasingly need guidance tailored to different populations and activities.

The geographic distribution of website traffic further illustrates that engagement. Texas has generated 63,511 views over the available period, more than four times the 14,862 recorded from North Carolina, where the tool was originally developed, and more than ten times Georgia, the third-highest state. North Carolina use has remained comparatively steady over the past several summers, suggesting an established user base in the tool's original service area. Other high-use states include Virginia, Illinois, Florida, New York, California, Missouri, and Ohio. California's relatively high traffic is notable because it falls outside the current forecast domain, underscoring an important limitation: location reflects a user's IP address and does not necessarily indicate where the forecast is being applied. Many of the highest-use states also have state or organization-specific WBGT guidelines available through the tool, reinforcing the importance of connecting forecasts with guidance users can act upon.

Website views do not represent individual users, nor do they reveal what decision someone made after visiting the site. They provide evidence of reach, but the experiences of users provide a more meaningful measure of value. SERCC and its partners have supported the tool through workshops, trainings, demonstrations, and direct engagement with organizations responsible for managing heat risk. One of the earliest examples came in June 2019, when the project team held an in-person workshop with athletic directors through a working group facilitated by the NCHSAA. Participants were introduced to the new WBGT forecasting tool and shown how it could complement the on-site measurements required under NCHSAA heat-safety guidelines (Figure 12). Just as importantly, the workshop gave researchers an opportunity to hear directly from athletic directors about the challenges of keeping student-athletes safe on dangerously hot days and the information they needed to make decisions about outdoor practices.

Those engagements have continued as the tool has grown, helping SERCC understand not only who needs heat information, but what happens once that information reaches them. Did someone change a practice time? Brief a commander? Adjust a work-rest schedule? Put additional precautions in place before dangerous heat arrived? The following stories show what happens after the forecast, how NOAA data, translated through SERCC science and decision-support services, can provide time to plan, time to communicate, and time to act.

Time to plan: before athletes take the field

For Michael Catterson, Head Athletic Trainer at Jenks High School in Oklahoma, the value of a forecast is measured in the decisions that can be made before athletes ever take the field. Catterson has used the WBGT Prediction Tool for at least three years and describes it as an essential resource for planning outdoor athletics. Rather than waiting to see what conditions are like at practice time, he uses the forecast to schedule activities when heat risk is lower and to make plans several days in advance. ***“Having a 3-4 day forecast also allows us to make plans for the week for all of our outdoor athletics,”*** Catterson explains. He typically checks the morning forecast when making his recommendation for outdoor activity and then returns to the tool as forecasts update during the day. When expected conditions change, that updated information helps him communicate adjustments to coaching staff more efficiently. Most importantly, Catterson says the forecast has allowed his school to schedule practices at appropriate times to minimize the risk of heat illness. He has also shared the tool with other athletic trainers so they can use the same information in their own programs.

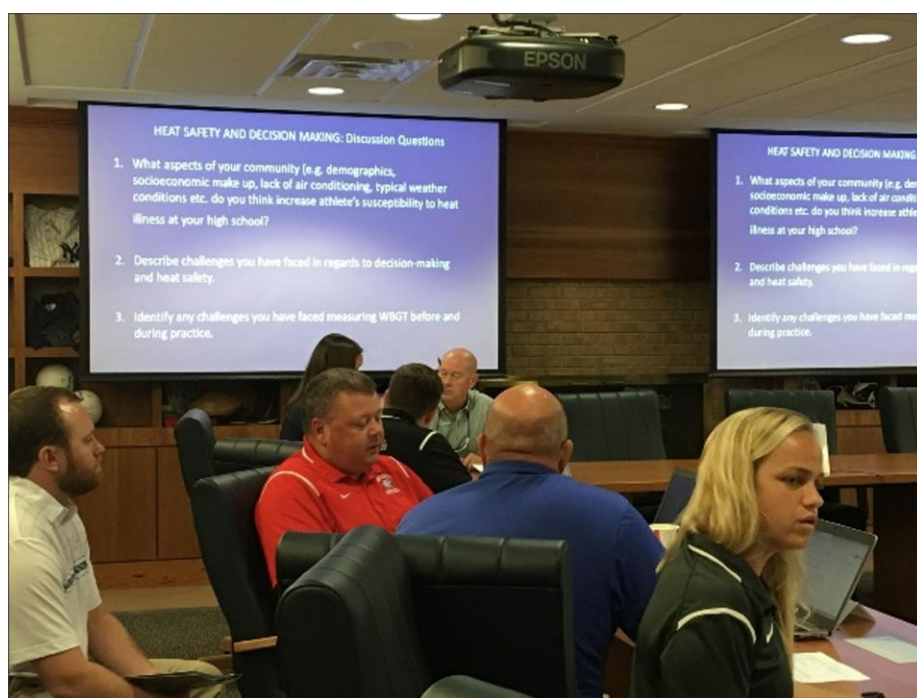


Figure 12. Athletic directors participate in a June 2019 workshop where SERCC researchers demonstrated the WBGT Prediction Tool and gathered feedback about heat-safety decisions and user needs.

Time to prepare: supporting military readiness

The same advance information can support decisions in a very different environment. At U.S. Army Garrison Fort Lee in Virginia, Kenneth Ray, Chief of the Operations Branch, uses weather information as part of the installation's Preparedness and Situation Insight Framework. The SERCC WBGT site and graphic, he says, have been particularly useful because they give commanders and leaders a clear picture of projected heat conditions in advance. When elevated WBGT is forecast, commanders have options. They can adjust training timelines,

move strenuous activity to earlier in the day, reinforce work-rest cycles, emphasize hydration, and ensure that other protective measures are ready before conditions become more hazardous. ***“Having that information ahead of time is much more effective than reacting after the heat has already intensified,”*** Ray explains. Even when a schedule does not change, he says the forecast supports better risk communication, more deliberate resource planning, and a stronger heat-safety posture. In his words, its value lies in giving leaders actionable information early enough to ***“help protect personnel and sustain operations.”***

Time to anticipate: filling operational gaps

Dr. Keith Brandt has spent four decades working in occupational, preventive, military, and aerospace medicine. Throughout that career, WBGT has been a fundamental part of managing heat risk. During deployments to hot-weather environments, including Qatar, Kenya, and Iraq, persistent black-flag conditions meant WBGT became part of operational briefings used by commanders to enforce hydration schedules and work-rest cycles. Today, similar principles apply to the remote expeditionary environments involved in aerospace operations. Those environments also illustrate why prediction matters. During recent operations supporting a Soyuz launch in Kazakhstan, where air temperatures exceeded 105 degrees F, restrictions prevented Brandt from bringing his personal WBGT meter. In circumstances where on-site monitoring is difficult or unavailable, he says predictive tools can provide critical situational awareness. While a calibrated instrument at the site remains the gold standard, forecast platforms such as the SERCC tool can fill an important operational gap by allowing medical and safety personnel to anticipate thermal stress, brief leadership in advance, and extend heat-safety guidance across large geographic areas. As he states, ***“In occupational and preventive medicine, true success means nothing dramatic happens—which makes quantifying the impact of heat mitigation inherently challenging.”***

Brandt's observation highlights a fundamental challenge in measuring the value of heat-safety information. When prevention works, the outcome may be an illness, injury, disruption, or emergency that never occurs. Establishing that a particular forecast prevented a specific emergency department visit, exertional heat illness, lost workday, or other adverse outcome would require a dedicated study linking tool use, individual decisions, heat exposure, and subsequent outcomes. Such an analysis has not yet been conducted for the WBGT Prediction Tool. What this study documents is the step immediately before those outcomes. Users are utilizing forecast information to change schedules, prepare resources, communicate risk, and put protective measures in place before dangerous heat arrives.

The NOAA data underlying the tool are only the beginning of the value story. Their value grows as they move through the chain illustrated in Figure 3. Data become information, information supports knowledge, knowledge informs decisions, and those decisions contribute to positive societal outcomes. The SERCC bridges these stages by combining NOAA's observing and forecasting capabilities with regional science, relationships, and knowledge of users.

To conclude, let's return to the coach standing beside a football field on a hot summer afternoon. The coach does not need to understand every NOAA dataset behind the forecast.

Nor does an emergency manager need to know every equation used to estimate WBGT. What they need is reliable information, presented at the right time and in a form that helps answer a question. Should practice continue? Should workers take additional breaks? Should activities move into the shade? Should additional hydration and cooling resources be put in place? Should an emergency manager activate additional resources? The value of the SERCC WBGT Prediction Tool is therefore not ultimately measured by how much NOAA data it processes or even by how many people click on its maps. Its value lies in the decisions those data make possible. The tool represents the culmination of sustained investment in NOAA observations and forecasts, applied science, partnerships, stakeholder engagement, and the continuous refinement of climate information around the needs of users. Its evolution from early heat-health research in North Carolina to an operational decision-support resource spanning much of the country and U.S. Caribbean shows what can happen when climate services begin not with the question “What data can we provide?” but with a more important one: “What decision are you trying to make?” By helping users answer that question, NOAA and the SERCC are transforming weather data into actionable guidance, and actionable guidance into safer, better-prepared, and more resilient communities.