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Goal

The Need for WBGT Information

- Since 1995, an average of 3 football players per year have died due to heat stroke (National Center for Catastrophic Sport Injury Research)
- High schoolers are vulnerable during afternoon summer practices
- WBGT is the standard measure for heat stress by the American College of Sports Medicine and U.S. Dept. of Defense, but there is a lack of WBGT monitoring
- Better forecasts for heat stress could be used to adjust practice schedules based on the expected heat threat throughout the week

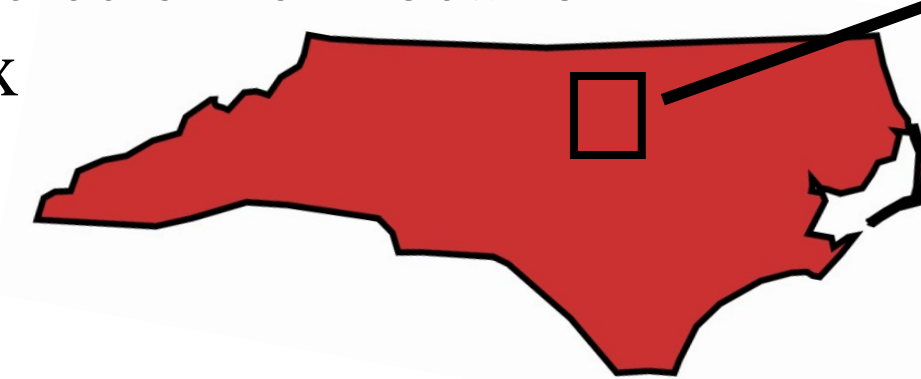
WBGT Decision Support Tool Goals

- Develop a publicly accessible interface for viewing WBGT forecasts
- Facilitate informed decisions about scheduling exertional outdoor activities
- Provide guidelines for actions to take in each WBGT risk category

Tool Highlights

Pilot Study Region

- Pilot region consists of 2 high schools that tested the WBGT tool against a heat stress device during summer 2018 and sent feedback
- For the experimental tool, the user selects their location within the pilot region bounding box



Tool Output

- For the user's specified location, the tool outputs hourly WBGT for the past 24 hours (RTMA) and the 5-day forecast (NDFD), requested by pilot study groups
- Top (black) line represents WBGT in full sunlight; bottom (gray) line represents WBGT in full shade/overcast conditions
- Users are notified of the highest WBGT category they may expect during the forecast period

WBGT Guidelines

- Guidelines for each WBGT category are provided for the user to take action and mitigate heat stress

Ways to Reduce Heat Stress

- **Move from a sunny area to the shade**, which can lower the WBGT risk category and **mitigate heat stress**
- Adjust practice time from after school to the evening to reduce heat stress
- Choose the day with lowest WBGT risk category to have tougher conditioning activities, if within the guidelines

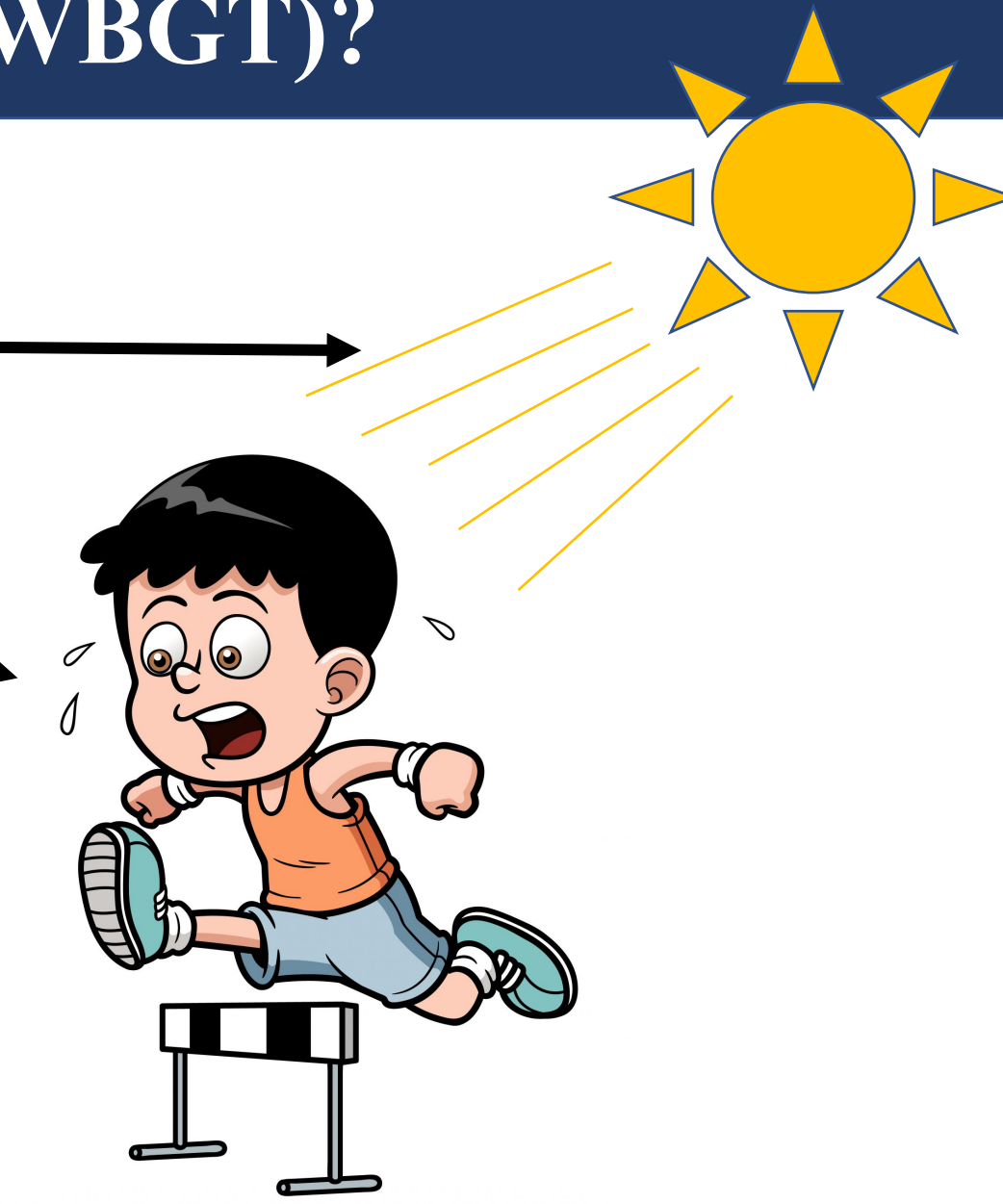


Comments or questions? We'd love your feedback! Scan the QR code for contact information or email dmbetra@ncsu.edu.

What is Wet Bulb Globe Temperature (WBGT)?

A measure of human heat stress that is based on:

- Black globe temperature (radiant heat)
- Natural wet bulb temperature (evaporative potential, or ability to sweat)
- Dry bulb temperature (heat in ambient air)



Heat index vs. WBGT

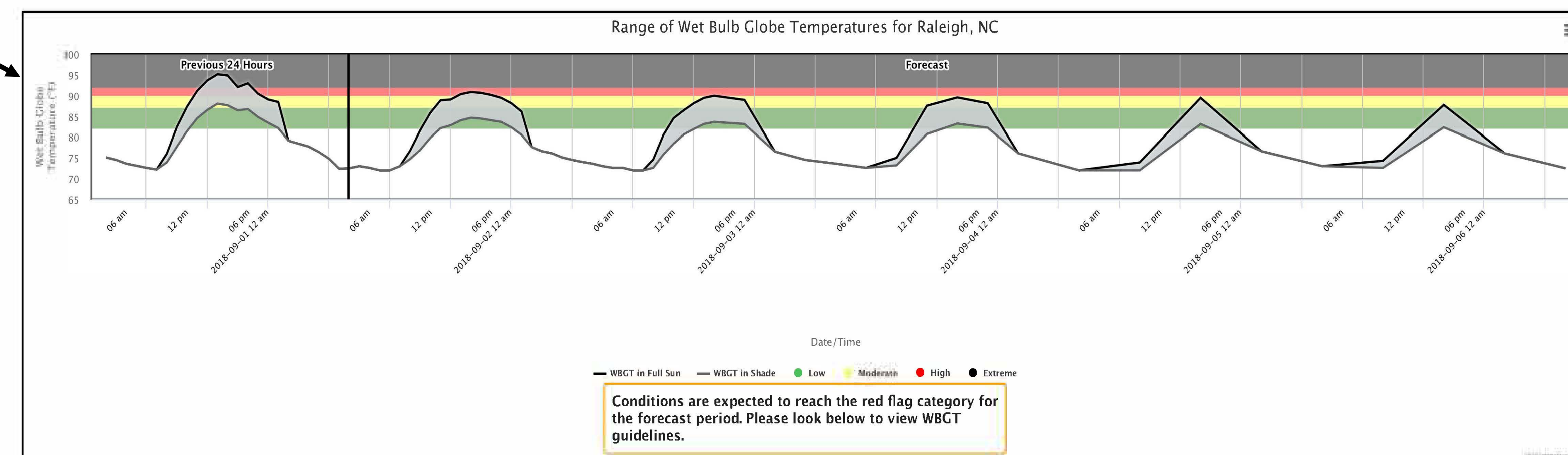
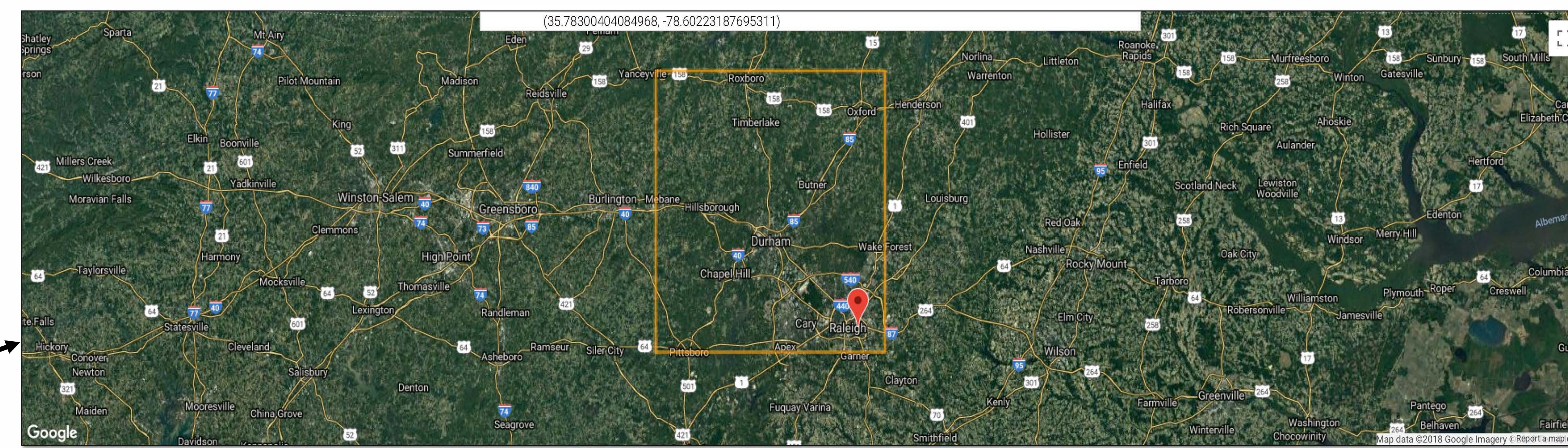
- Heat index: temperature, RH; measured in shade
- WBGT: temperature, RH, wind speed, solar radiation; measured in sun

Prototype of Tool

Wet Bulb Globe Temperature Decision Support Tool

Search for your location within the bounding box or select a location from the map below.

*Selecting a location outside of the bounding box will provide results from the nearest location within.



Conditions are expected to reach the red flag category for the forecast period. Please look below to view WBGT guidelines.

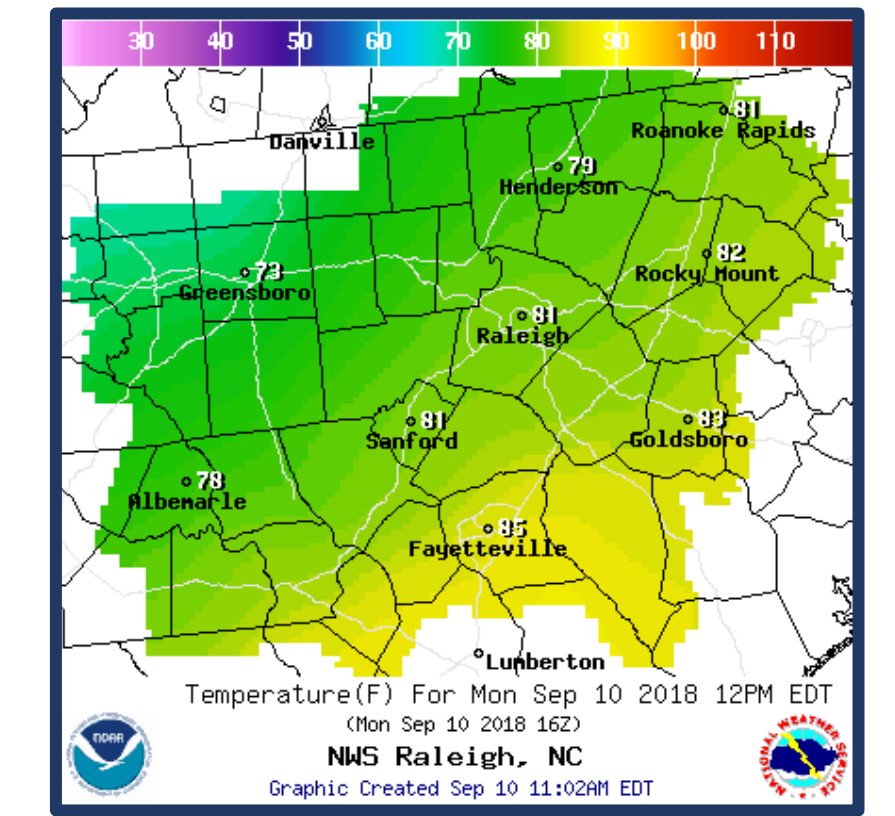
| Heat Category | WBGT Index (F) | Activity Guidelines |
|------------------------|----------------|---|
| No Flag | Under 82.0 | Normal activities - Provide at least 3 separate rest breaks each hour with a minimum duration of 3 minutes each during the workout. |
| Low (Green Flag) | 82.0 - 86.9 | Use discretion for intense or prolonged exercise; watch at-risk players carefully. Provide at least 3 separate rest breaks each hour with a minimum duration of 4 minutes each. |
| Moderate (Yellow Flag) | 87.0 - 89.9 | Maximum practice time is 2 hours. For Football: Players are restricted to helmet, shoulder pads, and shorts during practice, and all protective equipment must be removed during conditioning activities. If the WBGT rises to this level during practice, players may continue to work out wearing football pants without changing to shorts. For All Sports: Provide at least 4 separate rest breaks each hour with a minimum duration of 4 minutes each. |
| High (Red Flag) | 90.0 - 92.0 | Maximum practice time is 1 hour. For Football: No protective equipment may be worn during practice, and there may be no conditioning activities. For All Sports: There must be 20 minutes of rest breaks distributed throughout the hour of practice. |
| Extreme (Black Flag) | Over 92.0 | No outdoor workouts. Delay practice until a cooler WBGT level is reached. |

Source: Georgia High School Athletics Association; For more details, visit <https://www.ghsa.net/practice-policy-heat-and-humidity>.

Methodology

Gridded Data:

- Past 24 hours: Real-time Mesoscale Analysis (RTMA)
- 5-day Hourly Forecast: National Digital Forecast Database (NDFD)



Method of WBGT Estimation

- Standard equation for WBGT, but many methods to calculate NWB and GT from meteorological variables

$$WBGT = 0.7NWB + 0.2GT + 0.1DB,$$

where NWB is natural wet bulb temperature, GT is black globe temperature, and DB is dry bulb temperature

- **Liljgren et al. 2008:** best method for the SE region
- Inputs: temperature, dew point temperature, wind speed, relative humidity, solar radiation (est. from cloud cover), pressure (est. by typical summertime value)

WBGT Sun and Shade Estimations

- *Sun:* 0% cloud cover *Shade:* 100% cloud cover
- Provides a range of WBGT values for the user

Validation

Validation

- WBGT estimations were compared to measurements taken from Kestrel 4400s at 2 test sites in the Piedmont
- Found that the tool overestimates WBGT by a few degrees F and wind speed plays a big role in WBGT
- Will adjust values from the tool to more closely align with Kestrel, used by high schools in North Carolina



Kestrel 4400

Future Work

- Perform additional validation for various surface types
- Expand the tool to the Southeast U.S.
- Incorporate additional user groups (children, average citizens that are acclimated/unacclimated to the heat)
- Provide maps of forecasted WBGT across the SE

Acknowledgements

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