

# Human Heat Vulnerability: The Development of a Web-Based Tool for Predicting Heat Stress Among High School Athletes

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## Background

- Wet-Bulb Globe Temperature (WBGT) is a better metric of heat severity than heat index (HI), as it includes not only air temperature, humidity, but also solar radiation, and wind speed
- SERCC and CISA created a five day WBGT forecast tool that currently covers Virginia and North Carolina and will soon be expanded to rest of the continental US
- Uses inputs from the gridded National Weather Service's NDFD model for days 1 – 3 and the NBM model for days 4 – 5 to translate different variables to a WBGT estimate

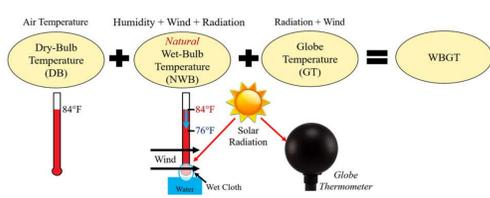


Figure 1: Breakdown of WBGT Formula  
Source: Southeast Regional Climate Center

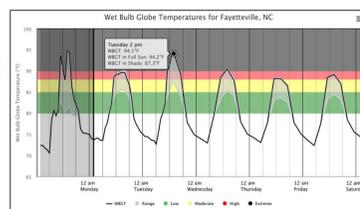


Figure 2: WBGT Tool  
Source: Southeast Regional Climate Center

## Methodology

### Data

#### Measured data:

- Observations were taken during football practice times at seven high schools across North Carolina during late summer to early fall of 2019

#### Model data:

- Two models were used: National Blend of Models (NBM) and National Digital Forecast Database (NDFD)
- Four runs of the input forecast data per day (00Z, 06Z, 12Z, 18Z)
- NDFD model had less forecast data than NBM model
  - NDFD: hourly (0-36), 3 – hourly (39-72), 6 – hourly (78-168)
  - NBM: hourly (0-36), 3 – hourly (39-192), 6 – hourly (198-264)

#### Methods

- Biases were calculated for a range of forecast hours (from 6 – hours to five – days in advance using the following formula:

$$\text{Bias} = \text{forecasted WBGT} - \text{measured WBGT}$$

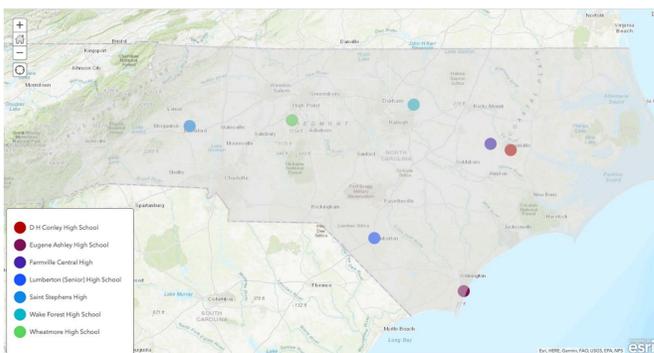


Figure 3: High school locations across North Carolina where measurements were taken  
Source: ArcGIS

## Summary Data Table

Table 1. Summary of observations taken for seven high schools in North Carolina during summer of 2019 for both NBM and NDFD Models.

Analysis	High Schools						
	Eugene Ashley HS	DH Conley HS	Lumberton HS	Farmville Central HS	Wheatmore HS	St. Stephens HS	Wake Forest HS
<b>Landscape Type</b>	Open	Open	Open	Open	Open	Sheltered	Sheltered
<b>Average Wind Speed (mph)</b>	3.48 (3.50)	2.92 (2.93)	2.86 (2.82)	2.60 (2.68)	2.51 (2.51)	1.30 (1.30)	1.04 (1.04)
<b>Total # of Observations</b>	174 (148)	220 (203)	114 (102)	105 (99)	137 (120)	67 (65)	210 (183)
<b>Percentage of Total Observations</b>	16.94% (16.09%)	21.42% (22.07%)	11.10% (11.09%)	10.22% (10.76%)	13.34% (13.04%)	6.52% (7.07%)	20.45% (19.89%)
<b># of Observations in the Morning (6am - 10am)</b>	52 (30)	35 (28)	6 (0)	2 (2)	35 (25)	0 (0)	66 (53)
<b># of Observations Midday (11am - 2pm)</b>	3 (3)	20 (18)	3 (1)	1 (1)	18 (14)	0 (0)	42 (42)
<b># of Observations in the Evening (5pm - 9pm)</b>	94 (91)	97 (93)	53 (51)	66 (62)	50 (48)	40 (39)	58 (53)
<b>Average WBGT Bias (Temp)</b>	0.308 (0.113)	-1.19 (-1.28)	1.58 (1.41)	-0.747 (-0.743)	2.49 (2.34)	-1.60 (-1.44)	1.25 (1.21)
<b># of Observations for 6-hour bias</b>	174 (140)	220 (194)	114 (102)	105 (95)	137 (115)	67 (62)	210 (181)
<b># of Observations for 12-hour bias</b>	174 (142)	220 (194)	114 (102)	104 (95)	137 (113)	67 (62)	210 (179)
<b># of Observations for 18-hour bias</b>	174 (136)	220 (193)	114 (97)	105 (95)	137 (113)	67 (63)	210 (176)
<b># of Observations for one-day bias</b>	174 (127)	220 (178)	114 (97)	105 (87)	137 (109)	67 (57)	210 (176)
<b># of Observations for two-day bias</b>	56 (45)	61 (56)	35 (29)	33 (32)	41 (34)	23 (22)	64 (60)
<b># of Observations for three-day bias</b>	56 (15)	61 (12)	35 (2)	33 (5)	41 (7)	23 (0)	64 (36)
<b># of Observations for four-day bias</b>	56 (15)	61 (11)	35 (2)	33 (5)	41 (7)	23 (0)	64 (36)
<b># of Observations for five-day bias</b>	56 (14)	61 (10)	35 (2)	33 (5)	41 (6)	23 (0)	64 (35)

\* Data format: NBM Model (NDFD Model)

## Results

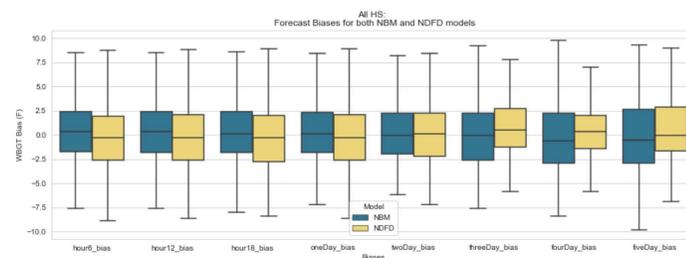


Figure 4: Change in forecast bias by forecast hour for both the NBM and NDFD models. The NBM model has a slight positive bias compared to the NDFD model which has a negative bias that is closer to zero (0.753 vs. -0.096)

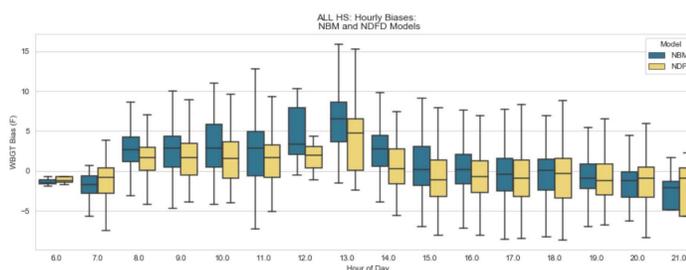


Figure 5: Change in forecast bias by hour of day for both the NBM and NDFD models. Both model's bias increase and peak by the middle of the day then decrease throughout the evening hours.

## Results

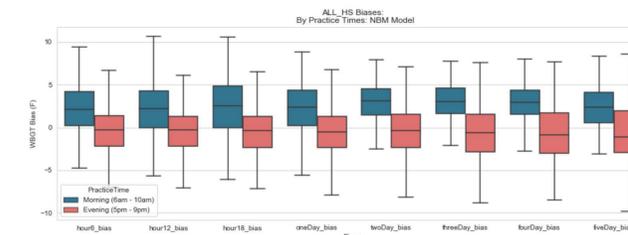


Figure 6: Change in bias by forecast hour for morning and evening practice times. Morning practice times had a consistent higher bias across all forecast hours due to lower wind speeds and increased cloud cover.

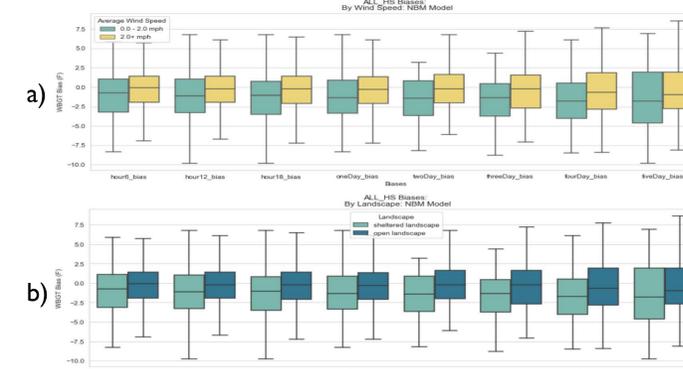


Figure 7: Change in bias by forecast hour for a) average observed windspeed and b) landscape type. Schools with a higher average wind speed and more open landscape saw consistent higher bias for all forecast hours.

## Discussion and Future Research

### Discussion

- The morning hours have a greater bias than evening hours
- Microclimate/landscape has major influence in WBGT forecast bias
- Lower wind speeds have much greater influence on bias than higher wind speeds
- WBGT Tool will be improved by incorporating landcover information (e.g. surface roughness) to account for differences across microclimates.

### Future Research:

- Mapping and exploring vulnerability to heat acclimatization on a variety of factors such as:
  - Behavioral/environmental factors (ex. poverty)
  - Health related factors (ex. asthma)

## Acknowledgements:

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