National Aeronautics and Space Administration

Analysis of the Dryden Wet Bulb Globe Temperature Algorithm for White Sands Missile Range

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Background

- Wet Bulb Globe Temperature (WBGT) is used as a measure of the heat load that a person is actually experiencing. It is usually measured by an instrument that uses natural wet bulb, black globe, and ambient temperatures. In lieu of these instruments, a standard meteorological recording station can be used. Since WBGT cannot be measured directly with this method, an algorithm is necessary. Currently, these algorithms need to be tailored for specific locations and climates.

  The following equation was developed for use at Dryden Flight Research Center (DFRC), and uses ambient temperature (Ta), relative humidity (RH), and wind speed (Ws) measurements.

$$WBGT = (0.567 \bullet Ta) + 0.393\left(\left(\frac{RH}{100}\right) \bullet \left(6.112 \bullet \exp\left(\left(\frac{17.67 \bullet Ta}{Ta + 243.5}\right)\right)\right)\right) + 5.05 - (0.297 \bullet Ws)$$

Heat Stress Flags

- The following scale is used to determine the amount of work that is allowed to be done when the WBGT is at certain levels.

Categories	Minimum, °C	Maximum, °C	Work demands
Green	27.8°	29.3°	Discretion required
Yellow	29.4°	31.0°	75% work, 25% rest
Red	31.1°	32.1°	50% work, 50% rest
Black	32.2°	No limit	25% work, 75% rest

- White Sands Missile Range (WSMR) is currently relying on a WBGT instrument, and a viable WBGT algorithm to be used with a surface observation system would be useful for them. Due to the climatology similarities between DFRC and WSMR, it is thought that the DFRC algorithm might be applicable.

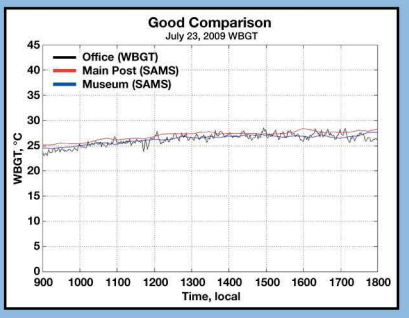
  A point of concern is the summer monsoons, which leads to WSMR having a higher relative humidity than DFRC.

Instruments Used

- WBGT Suite
  - Natural wet bulb thermometer
  - Black globe thermometer
  - Ambient thermometer
  - One minute observations
- Surface Atmospheric Measurement Systems (SAMS)
  - Ambient thermometer
  - Hygrometer
  - Anemometer
  - Fifteen minute observations
- This study was focused on the period of 0900 to 1800, local time.

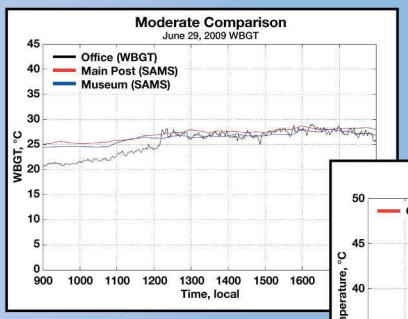
Comparison Criteria

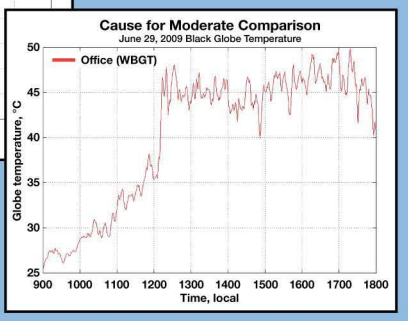
- For this study there were three categories
  - Good = Difference < 1° C
  - Moderate = 1° C < Difference < 2° C
  - Poor = Difference > 2° C



Moderate Comparison

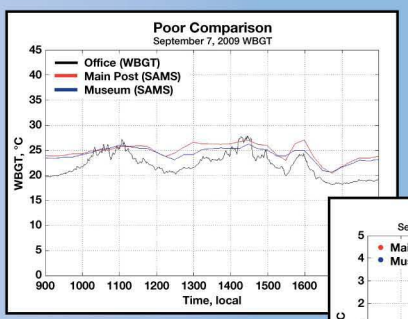
- In this example, the early discrepancy between the measured and calculated WBGTs can be explained by examining the various inputs. The low black globe temperature corresponds directly with the lower measured WBGT, and can be attributed to cloud cover. Once the black globe temperature rises, the measured WBGT rises to a good comparison with the calculated WBGTs.

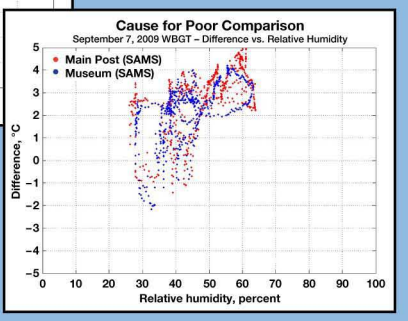




Poor Comparison

- In this example, the measured WBGT rarely matches with the calculated WBGTs. By examining the various components, the cause of such a poor comparison can be determined. It can be seen that the amount of discrepancy increased once the relative humidity was over 35 percent.





Results

- 23 out of 30 examined days fell under acceptable accuracy.
- An issue with the calculated WBGTs was the increased error when the relative humidity was over 35 percent.
- Instruments with a rate better than 15 minute intervals would be preferrable, so that short duration heat stress events are not missed.