Creating a Wet Bulb Globe Temperature Calculation for MetPy

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What is WBGT?

Wet Bulb Globe Temperature (WBGT) is a measure of the heat stress in direct sunlight, which takes into account temperature, humidity, wind speed, sun angle and cloud cover.

How it differs from Heat Index (HI)?

Both HI and WBGT take into temperature and humidity, WBGT differs by taking into account shaded areas

Temp F	Dwpt F	RH %	Sky %	Wind mph	HeatIdx F	WBGT F
90	65	42	05	03	92	89
90	65	42	05	13	92	83
90	65	42	65	13	92	81
90	70	52	10	06	96	88
90	70	52	60	06	96	86
90	70	52	60	13	96	85
100	70	39	10	13	108	90
100	70	39	10	5	108	94
100	70	39	65	05	108	91

Table 1: Comparison of WBGT and Heat Index provided by NWS

Why add this to MetPy?

The National Weather Service is attempting to include WBGT in their gridded forecast products

WBGT = 0.7Tw + 0.2Tg + 0.1Ta

Tw – Wet Bulb Temperature

Tg – Globe Temperature

Ta – Apparent Temperature

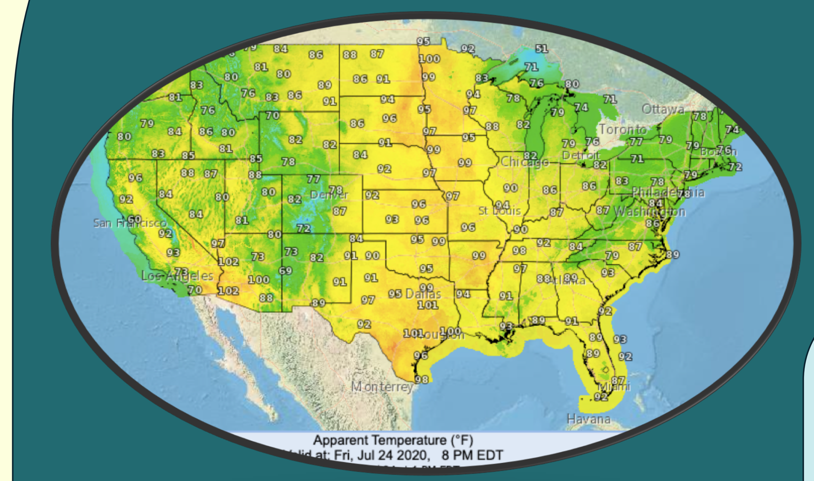

Figure 1: Apparent temperature graphical forecast provided by NWS

Variables easy to calculate:

- Wet bulb temperature ✓
- Dry bulb temperature ✓
- Globe temperature ✗

Calculation #1 to compute globe temperature[1]:

$$e_a = \exp\left(\frac{17.67(T_d - T_a)}{T_d + 243.5}\right) \times (1.0007 + 0.00000346P) \times 6.112\exp\left(\frac{17.502T_a}{240.97 + T_a}\right)$$

$$\varepsilon_a = 0.575 e_a^{(1/7)}$$

$$B = S\left(\frac{f_{db}}{4\sigma\cos(z)} + \left(\frac{1.2}{\sigma}\right) f_{dif}\right) + (\varepsilon_a) T_a^4, \text{ where } \sigma = 5.67\times10^{-8}$$

$$C = \frac{hu^{0.58}}{(5.3865\times10^{-8})}, \text{ where } h = 0.315$$

$$T_g = \frac{B + CT_a + 7680000}{C + 256000}$$

Calculation #2 to compute globe temperature[2]:

$$T_g^4 = \frac{1}{2}(1+\varepsilon_a)T_a^4 - \frac{h}{\varepsilon_g\sigma}(T_g - T_a) + \frac{S}{2\varepsilon_g\sigma}(1-\alpha_g)\left[1 + \left(\frac{1}{2\cos(\theta)} - 1\right) f_{dir} + \alpha_{sfc}\right]. \tag{17}$$

What went wrong?

Calculation #1:

- Trouble finding solar irradiance values
- How to calculate diffuse and direct beam flux
- Units
- Zenith angle (attempted to create my own solar position calculator)
- Tg value extremely off

Calculation #2:

- Zenith angle
- Figuring out correct value for convective heat transfer coefficient (h)
- Creating iterative code to solve for Tg

And then:

- Found way to calculate solar irridance, Tg still off
- Figured out how to calculate Fdif and Fdir, Tg still off
- Learned how to calculate h,Tg still off
- Coded Tg to solve iteratively, Tg still not right

What went right?

- Learned how to code in Python
- Expanded my knowledge on solar positions, time zones, and sun angles
- Contributing what I have to MetPy so one day there will be a functional WBGT calculation

References

[1] Dimiceli V, Piltz, S. Estimation of Black Globe Temperature for Calculation of the WBGT Index. https://www.weather.gov/media/tsa/pdf/WBGTpaper2.pdf.

[2] Liljegren JC, Carhart RA, Lawday P, Tschopp S, Sharp R. Modeling the wet bulb globe temperature using standard meteorological measurements. Journal of Occupational and Environmental Hygiene 2008;5(10):645-655.