Estimation of WBGT with JMA products and information web site for heat stroke in Japan

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1. INDEX FOR HEAT DISORDERS IN JAPAN

There are several indexes related to heat disorders, and in U.S.A. 'Heat Index' is well known and often used to warn the risk of heat diseases. On the other hand, WBGT (Wet Bulb Globe Temperature, Yaglou, 1957) is adopted as ISO 7243 especially for working people. In Japan, Japan Amateur Sports Association published 'A guidebook for prevention of heat disorders for sporting activities' in 1994, and in this guidebook, WBGT is introduced as an index to judge the risk of heat diseases.

Additionally in an instruction regarding prevention for heat diseases, issued by Labor Ministry in 1997, WBGT is adopted as an index for heat diseases risks. At now, WBGT is often used as an index to judge the risk of heat diseases in Japan.

Table 1. Risk levels of heat disorders. Japan Amateur Sports Association (1994)

WBGT threshold (degrees C)		
31	danger	Stop exercises in principle
28	alert	Stop severe exercises
25	advisory	Take rests frequently
21	caution	Frequent hydration
	almost safe	Risk is relatively lower

WBGT is calculated from T_w (wet bulb temperature), T_g (globe temperature) and T_a (dry bulb temperature) as follows.

$$WBGT = 0.7 \times T_w + 0.2 \times T_g + 0.1 \times T_a \quad \text{(outside)}$$

$$WBGT = 0.7 \times T_w + 0.3 \times T_g \quad \text{(inside)} \qquad (1)$$

2. WBGT from re-analysis data issued by JMA.

To calculate WBGT, we have to observe or estimate T_a, T_w and T_g. T_a is equal to temperature itself, and T_w is approximated from temperature, relative humidity and pressure (Iribarne , 1981). T_g is calculated by experimental equations (based on 2006 to 2008 observation data at 6 major cities in Japan) as follows.

$$T_g = T_a + 12.1 + 0.0067 \times S - 2.40 \times U^{1/2} \quad (S>400W/m^2)$$

$$T_g = T_a - 0.3 + 0.0256 \times S - 0.18 \times U^{1/2} \quad (S<=400W/m^2) \qquad (2)$$

here, Ta: dry-bulb temperature(degree in Celsius), S: sun radiation (W/m^2), U: wind speed(m/s)

We estimated WBGT from reanalysis data (temperature, wind and cloud) and MSM (Meso-Scale Model) data both issued by JMA. Reanalysis (spatial resolution is 20km <cloud> or 5km <other factors>) data is issued in 1 hourly interval and MSM is issued in 3 hourly interval and both data include 1 hourly meteorological factor at the surface layer. However, MSM products do not include sun radiation, so we estimate sun radiation from cloud amount, observatory location and local time. Sun radiation is estimated by equations proposed by NEDO(1995) and the following equation.

$$S = Y \times S_f \qquad (3)$$

$$Y = 1.70 \times \log_{10}(1,22-1.02 \times X) + 0.521 \times X + 0.846 \quad (n>=0.3)$$

$$= 1 \quad (n<0.3)$$

$$X = n - 0.4 \times \exp(-3n_L)$$

here, S_f is sun radiation without clouds (W/m^2) and y is an attenuation coefficient, and n_L is a low cloud amount (Kondo, 1994).

Re-analysis data and cloud analysis data is issued in 1 hourly interval, however, MSM data is issued in 3 hourly interval, so for example at 1 or 2 UTC, relative humidity or pressure data is not re-analysis data but forecast data 1 or 2 hours ahead from its initial time.

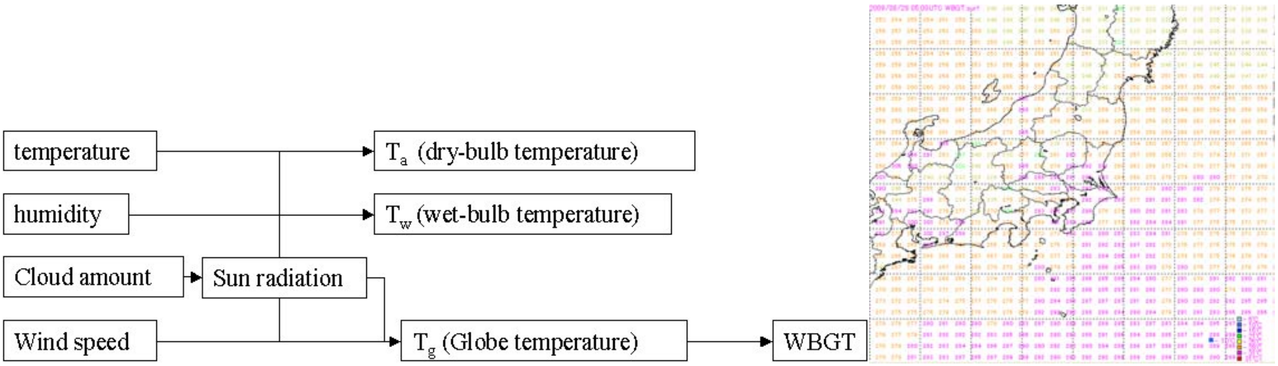
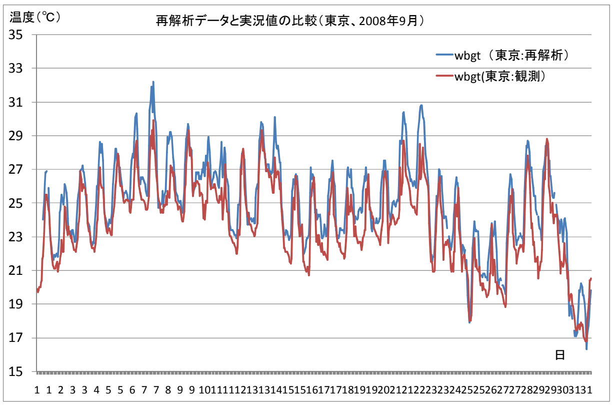


Fig. 1. A flowchart of WBGT estimation



	Tokyo	Hachioji	Nerima
average	1.2	0.3	1.1
maximum	4.3	6.4	5.5
minimum	−1.6	−3.7	−4.6
standard deviation	1.0	1.4	1.5

Fig. 2. An evaluation of estimated WBGT (Aug. 2009)

Fig.2 is an evaluation result of estimated WBGT in August 2009 at Tokyo, Hachioji and Nerima. It reveals that estimated WBGT has a plus bias compare to observed WBGT and the standard deviation of error is around 1 degree in Celsius. We think the estimated WBGT can explain differences between 2 areas or a trend of WBGT at the point roughly. The standard deviations of estimated WBGT are 1.0 to 1.4 degree, and standard deviation at Tokyo is smaller than Hachioji and Nerima, because the daily range in temperature at Tokyo is smaller than other 2 cities.

And then we investigated which factor brings a major error on the estimated WBGT. Fig.3 and table 2 is a statistic value of factors at Tokyo in august 2009. Though re-analysis temperature has only 0.2 degree bias, globe temperature has 3.0 degree bias and wet-bulb temperature has 0.8 degree bias. The error is come from inaccuracy of a plus bias of relative humidity and the error of cloud amount value at the point. In daylight estimated WBGT mostly has a plus bias mainly caused by relative humidity error.

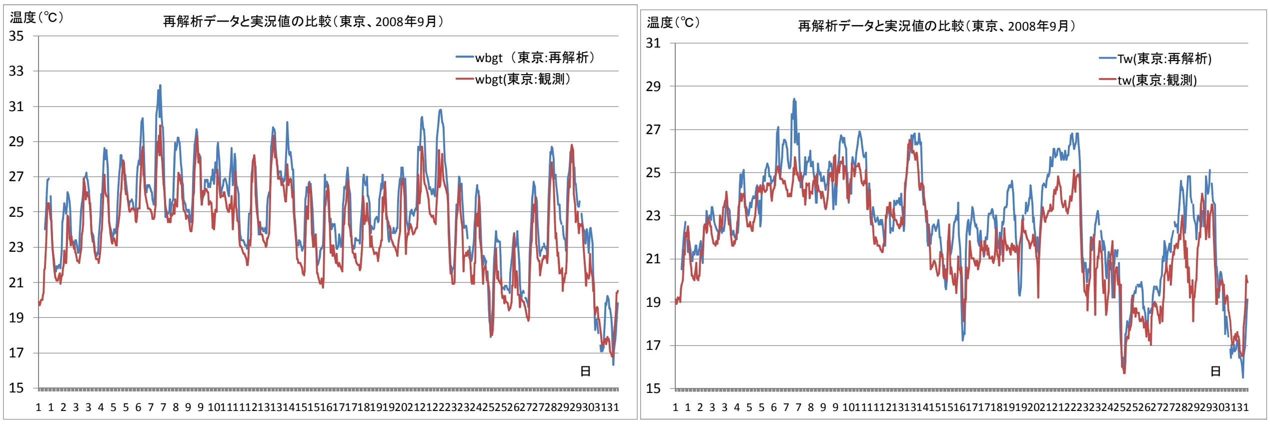


Fig. 3. A comparison of estimated Tw and WBGT and observed data at (Tokyo, August/2009)

Table 2. Statistical values of estimated WBGT (Tokyo, August/2009)

	WBGT	temperature	wet-bulb temperature	globe temperature
average	1.2	-0.2	0.8	3.0
maximum	4.3	0.7	5.6	16.6
minimum	-1.6	-1.5	-2.7	-1.4

3. Discussion

With using JMA reanalysis data, we can estimate WBGT in 1 degree accuracy in Celsius. However, because of error in relative humidity and cloud amount, there remains plus bias mainly in daylight. We're planning to improve the estimated WBGT by calibrating with AWS (AMeDAS) data.

Reference

(1) Yaglou, C.P. and Minard, C.D.: Control of casualties at military training centers, AM. Med. Ass. Archs. Ind. Health 16, 302-306, 1957

(2) Kondo J.: meteorology in hydro-environment studies (in Japanese), 1994

(3) NEDO: A study for solar power systems and related methods (in Japanese), 1996

(4) Huschke R. E.: Glossary of Meteorology. American Meteorological Society, 638 pp., 1959

(5) Iribarne, J. V., and W. L. Godson: Atmospheric Thermodynamics. 3rd ed. D. Reidel, 259 pp, 1981

(6) Ministry of Environment: A guide book for preventing heat diseases (in Japanese), 2006