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.

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

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

\[
WBGT = 0.7 \times T_w + 0.3 \times T_g \quad \text{(inside)}
\]

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.

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

\[
T_g = T_a - 0.3 + 0.0256 \times S - 0.18 \times U^{1/2} \quad (S\leq400\,\text{W/m}^2)
\]

here, $T_a$: dry-bulb temperature (degree in Celsius), $S$: sun radiation ($\text{W/m}^2$), $U$: 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.

\[
S = Y \times S_f
\]

\[
Y = 1.70 \times \log_{10}(1.22-1.02 \times X) + 0.521 \times X + 0.846 \quad (n>0.3)
\]

\[
= 1 \quad (n<0.3)
\]

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

here, $S_f$ is sun radiation without clouds ($\text{W/m}^2$) 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

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

<table>
<thead>
<tr>
<th></th>
<th>WBGT</th>
<th>temperature</th>
<th>wet-bulb temperature</th>
<th>globe temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>average</td>
<td>1.2</td>
<td>-0.2</td>
<td>0.8</td>
<td>3.0</td>
</tr>
<tr>
<td>maximum</td>
<td>4.3</td>
<td>0.7</td>
<td>5.6</td>
<td>16.6</td>
</tr>
<tr>
<td>minimum</td>
<td>-1.6</td>
<td>-1.5</td>
<td>-2.7</td>
<td>-1.4</td>
</tr>
</tbody>
</table>

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

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