Information Sciences

Improved Heat-Stress Algorithm

Corrections for solar radiation and wind increase the accuracy of determining dangerous outdoor work environments.

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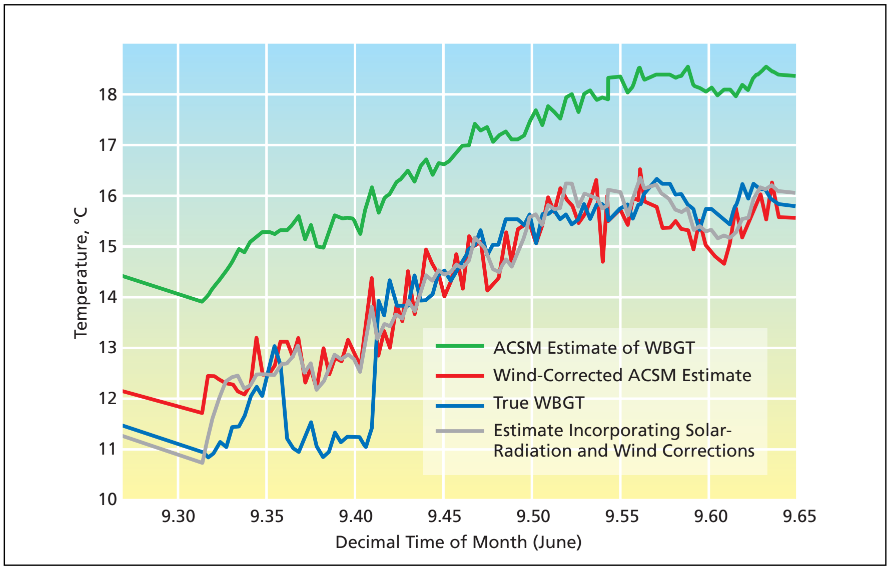
NASA Dryden presents an improved and automated site-specific algorithm for heat-stress approximation using standard atmospheric measurements routinely obtained from the Edwards Air Force Base weather detachment. Heat stress, which is the net heat load a worker may be exposed to, is officially measured using a thermal-environment monitoring system to calculate the wet-bulb globe temperature (WBGT). This instrument uses three independent thermometers to measure wet-bulb, dry-bulb, and the black-globe temperatures. Two reasons for this project were limited access to the Dryden monitoring system and delays of the required manual issuances for heat-stress warnings.

Existing algorithms to estimate the WBGT are less applicable in dissimilar environments. The American College of Sports Medicine (ACSM) was the algorithm selected after being used extensively and successfully during the 2000 Summer Olympics in Sydney, Australia. The ACSM algorithm only uses dry ambient temperature and vapor pressure to estimate the WBGT and it assumes moderate solar radiation and low wind speeds. However, when applied to extreme environments such as the Southwest desert region, this algorithm produces less than acceptable WBGT values. This situation increases the likelihood of overlooking unsafe conditions for employees working outdoors.

Dryden provided corrections to the environmental assumptions of moderate solar radiation and low wind built into the algorithm. Desert environments, such as the high Mojave in Southern California, have both high solar radiation (1,000 W/m^2) and periods of significant winds during the summer afternoons in excess of 20 kn. When comparing the difference between the thermal environment monitor WBGT (actual) and the ACSM approximated WBGT against wind speed, it was found that a direct relationship existed with a positive slope (i.e., a large difference between the actual and estimated WBGT as the wind speed increases). A correction curve based on 40 days of comparisons was applied, and significant improvements to the WBGT approximations were observed. The daily difference between actual and calculated WBGT was reduced from approximately 2.0° to about 0.5° on the average.



ACSM Estimates of WBGT were brought closer to true WBGT values by applying corrections for wind and solar radiation.

Next, the moderate solar radiation assumption had to be addressed and was corrected by a similar process as that for the wind. Since at noon the solar radiation was the highest, the adjustments began there. The approximation algorithm produced reasonable values during the hours when the Sun was at its peak, but there were large overestimates in the morning and at night. To correct this, the differences between the actual and estimated WBGT were compared to solar radiation measurements. The results from this were again used to create another correction curve. The difference between actual and calculated WBGT was reduced from approximately 2.0° to about 1.5° on the average. Combining the two curves improved the estimation significantly better than 0.5° on the average for the 40 days.

By using these improvements, a more realistic WBGT estimation value can now be produced. A variety of advantages come as a result of this. One of the most useful advantages is that a Web-based system can now be developed to automate and archive these calculations at a high update rate so that data are available everywhere for everyone. This Web automation system, in turn, will save meteorologists and safety personnel a considerable amount of time because they will no longer have to periodically record and archive WBGT measurements throughout the workday. Not only will the new algorithm help free up personnel but it will also make the thermal environment monitoring systems available to obtain site-specific WBGT data. This is extremely useful for researchers and other employees who are working on outdoor projects that are distant from the areas that the Web system monitors. Most importantly, the improved WBGT estimations will make outdoor work sites safer by reducing the likelihood of heat stress.

This work was done by Edward H Teets, Jr., of Dryden Flight Research Center and Steven Frehn of Highland High School (Palmdale, CA). Further information is contained in a TSP (see page 1). DRC-05-01