Vol. 58: 183–191, 2013
doi: 10.3354/cr01199

CLIMATE RESEARCH
Clim Res

Published December 9

Exceedance of wet bulb globe temperature safety thresholds in sports under a warming climate

Andrew Grundstein[1,*], Nellie Elguindi[2], Earl Cooper[3], Michael S. Ferrara[4]

[1]Department of Geography, University of Georgia, Athens, Georgia 30602, USA
[2]Earth System Physics Section, The Abdus Salam International Centre for Theoretical Physics, Strada Costiera, 11, 34151 Trieste, Italy
[3]Department of Kinesiology, University of Georgia, Athens, Georgia 30602, USA
[4]College of Health and Human Services, University of New Hampshire, Durham, New Hampshire 03824, USA

ABSTRACT: Extreme heat poses a serious health threat, particularly for people like athletes, soldiers, and workers engaged in outdoor physical activity. For athletes, the American College of Sports Medicine (ACSM) specifies environmental risk categories based on the wet bulb globe temperature (WBGT). We examined the present and future frequency of days that exceed the most extreme ACSM risk category (>32.3°C), when training and practice activities should cease. Using a physically based model, the WBGT was computed for present (1991–2005) climate conditions using standard weather observations and for future (2041–2070) climate conditions using an ensemble of regional climate model output. Results indicate diverse spatial patterns of exceedance across the US in the present-day climate, ranging from <5 d yr^{-1} in northern portions of the country to >50 d yr^{-1} across portions of the southeastern US and southern Arizona. Under a warming climate, the frequency of days unsuitable for practice sessions according to current ACSM guidelines increases considerably, ranging from 15 to >30 d yr^{-1} in broad swaths of the country. Further, our temporal analysis revealed an expansion in the threat for extreme heat through the day ranging from late morning through early evening, although early mornings remain one of the safest periods to avoid heat exposure. Various adaptation strategies such as shifting practice times and developing heat acclimatization plans may be useful in mitigating the impacts of more frequent oppressive days on training sessions.

KEY WORDS: Climate change · Wet bulb globe temperature · Heat illness · Sports · United States

1. INTRODUCTION

Extreme heat has an adverse effect upon human health (O'Neill & Ebi 2009). Already, there is a greater hazard from heat with the increasing frequency of oppressively hot days (Gleason et al. 2008, Hansen et al. 2012), and climate model projections of a warming climate indicate both longer and more intense heat waves (Meehl & Tebaldi 2004). Under these conditions, people such as athletes, soldiers, and workers engaged in strenuous outdoor physical activity may experience greater risks for exertional heat illnesses (EHI). The most serious EHI, heat stroke, may result in death. In the US, over 400 workers died from heat-related causes from 1992–2006 (Centers for Disease Control and Prevention 2008), and 123 athletes died over a period spanning 1960–2009 (Mueller & Colgate 2010).

Multiple biometeorological indices and models have attempted to capture thermal stress on humans (Epstein & Moran 2006). Several of the 'rational' indices or models are very comprehensive and consider the environmental and behavioral factors that influence the total human heat balance. From an operational standpoint, however, 'direct' indices that measure environmental conditions are most easily

*Email: andrewg@uga.edu

applied. Further, Epstein & Moran (2006) argued that direct indices in conjunction with guidelines that account for work intensity and clothing can effectively quantify the hazard for heat stress.

Our research focused on the wet bulb globe temperature (WBGT), as it is among the most widely used direct measures of heat exposure. The WBGT is a weighted average of the natural wet bulb (WB), dry bulb (DB), and globe (GT) temperatures and is calculated as follows: WBGT = (0.7 × WB) + (0.2 × GT) + (0.1 × DB) (Yaglou & Minard 1957). It is designed to capture the various environmental factors like sunlight, air temperature, wind, and humidity that can affect the human heat balance. The WBGT is the standard metric to monitor heat exposure officially used by US government agencies like the Occupational Safety and Health Administration (OSHA; OSHA 2012) and the US military (Departments of Army and Air Force 2003), as well as by organizations like the American College of Sports Medicine (ACSM), Sports Medicine Australia, the National Athletic Trainers' Association, the American Academy of Pediatrics, and the International Standards Organization (American Academy of Pediatrics 2000, Binkley et al. 2002, ISO 2003, Armstrong et al. 2007, Sports Medicine Australia 2012). Both OSHA and the US military, for instance, account for activity level and clothing type in assessing heat-related hazards by varying the allowable heat exposure as measured by the WBGT (Departments of Army and Air Force 2003, OSHA 2012). The ACSM does not make explicit reference to activity levels or levels of clothing in their safety guidelines, although recommendations are made regarding adjusting activity levels and providing increased rest periods during increasingly hot conditions. Additionally, many athletes who train during the warm season in sports like soccer and cross country running wear light clothing and little gear. Local heat policies based on the ACSM guidelines, however, often require adjustments to equipment under oppressive conditions. For example, the Georgia High School Association (GHSA) requires football players to limit equipment to helmets, shoulder pads, and shorts if the WBGT is 30.6–32.2°C (87.0–89.9°F) and to remove all protective gear during practices when the WBGT exceeds 32.2°C (90.0°F; GHSA 2013).

Several studies have used biometeorological indices or models to better capture how climate change may affect human comfort (e.g. Diffenbaugh et al. 2007, Jendritzky & Tinz 2009, Maloney & Forbes 2011), but only a few studies have explicitly looked at WBGT (e.g. Hyatt et al. 2010, Willett & Sherwood 2012). Our research builds upon these earlier studies and offers several advances. First, we utilized a physically-based WBGT model that explicitly accounts for all meteorological factors that can affect the components of the WBGT. Previous work used simplified equations that incorporated only air temperature and humidity as inputs (e.g. Willett & Sherwood 2012) or statistically based equations (e.g. Hyatt et al. 2010) to compute WBGT. In addition, we used an ensemble of high-resolution regional climate multi-model (RCM) data (3-hourly, 50 km) which will allow for better assessment of variations in WBGT over the day compared with using a global circulation model (GCM; e.g. Willett & Sherwood 2012) that offers lower spatial and temporal resolutions. Finally, no study has investigated changes in WBGT in response to climate change in the context of athletics and thresholds used by the ACSM (Armstrong et al. 2007) to assess safe practice and training conditions. EHIs are common problems among athletes, particularly among those that participate in prolonged, strenuous activity in hot, humid conditions (Armstrong et al. 2007). The ACSM maintains a set of thresholds where activity is adjusted (e.g. adjust length/intensity of practices or increase rest to work ratios) based on the WBGT (Armstrong et al. 2007).

Here we examined changes in the daily frequency of the most extreme conditions, when exercise/training should be canceled according to ACSM guidelines (WBGT >32.3°C), in the context of climate change across the contiguous US. At present, the National Collegiate Athletic Association (NCAA) and the National Football League (NFL) have both fully implemented acclimatization policies for their athletes (Korey Stringer Institute 2013). As of 2013, however, only 8 states have strong heat policies that have been endorsed by the National Athletic Trainers' Association and the Korey Stringer Institute for youth athletes (Korey Stringer Institute 2013). By placing the results in the context of the widely used ACSM safety thresholds, we hope that our study will clearly convey to those involved in interscholastic sports how climate change will affect athletes and their safety. We also hope that our study will help to inform and encourage the development of heat policies as a method to reduce vulnerability to heat-related illnesses.

2. DATA AND METHODS

This study follows a similar approach to Willett & Sherwood (2012) and examines the frequency of exceedance of established safety thresholds rather than the WBGT values themselves. In particular, we focused on the frequency of days where the WBGT exceeds the ASCM threshold of 32.3°C, when practice activity should cease. Modeled WBGT values rather than observations were used, as WBGTs are not commonly measured. The WBGT was computed for present conditions using standard weather observations (1991–2005), and for future climate conditions (2041–2070) from an ensemble of RCM output. Maps of average annual exceedance days for present and future conditions were produced along with a table of exceedance days by time of day for a sample of stations distributed across the contiguous US. The WBGT model and input data sources from observations ('NSRDB dataset') and climate model output ('Climate model') are described below.

2.1. WBGT model

A physically based model developed by Liljegren et al. (2008) was used to calculate the WB and GT components of the WBGT. The advantage of using a physically based model rather than a statistical model is that it has wide geographic applicability. Results from Liljegren et al. (2008) showed that the model successfully simulates measured WBGT values (accuracy ≤1°C) at sites located in diverse climates, including those in humid (e.g. Anniston, AL; Blue Grass, KY; Pine Bluff, AR; Newport, IN) and arid (e.g. Deseret, UT; Pueblo, CO; Umatilla, OR) locations.

The natural wet bulb temperature (T_w) is computed by considering the energy balance of the wick, including energy losses by evaporation (second term on the right hand side of Eq. 1) and energy gains via radiation and convective transfers of energy (third term on the right hand side of Eq. 1):

$$T_w = \underbrace{T_a}_{1} - \underbrace{\frac{\Delta H}{C_p}\frac{M_{H2O}}{M_{Air}}\left(\frac{Pr}{Sc}\right)^a\left(\frac{e_w - e_a}{P - e_w}\right)}_{2} + \underbrace{\left(\frac{\Delta F_{net}}{Ah}\right)}_{3} \quad (1)$$

where T_a is ambient air temperature, ΔH is the heat of vaporization, C_p is the specific heat at constant pressure, M_{H2O} is the molecular weight of water vapor, M_{Air} is the molecular weight of air, Pr is the Prandtl number, Sc is the Schmidt number, a is a constant = 0.56, e_w is the saturation vapor pressure of the wick, e_a is the saturation vapor pressure of the air, P is the barometric pressure, ΔF_{net} is the net radiant heat flux from the environment to the wick, A is the surface area of the wick, and h is the convective heat transfer coefficient which is computed in part from wind speed.

The globe temperature (T_g) is modeled by accounting for energy gains and losses to the globe by convective and radiative transfer mechanisms, where the first term on the right hand side of Eq. (2) represents transfers of thermal radiation from the air, the second term represents transfers of energy via convection, and the third term represents gains in energy from solar radiation:

$$T_g^4 = \underbrace{\frac{1}{2}(1+\varepsilon_a)T_a^4}_{1} - \underbrace{\frac{h}{\varepsilon_g \sigma}(T_g - T_a)}_{2} + \underbrace{\frac{S}{2\varepsilon_g \sigma}(1-\alpha_g)\left[1+\left(\frac{1}{2\cos(\theta)}-1\right)f_{dir} + \alpha_{sfc}\right]}_{3} \quad (2)$$

where ε_a is emissivity of the air, T_a is air temperature, h is the convective heat transfer coefficient, ε_g is the emissivity of the globe, σ is the Stefan-Boltzmann constant, S is the total horizontal solar irradiance, α_g is albedo of the ground, θ is the solar zenith angle, f_{dir} is the fraction of S that is direct beam radiation, and α_{srf} is the albedo of the surface. We utilized the default values used by Liljegren et al. (2008) of ε_g = 0.95, α_g = 0.05, and α_{sfc} = 0.45 in model simulations. Both the wet bulb and globe temperature equations are solved using iterative numerical solutions. Further details on the above equations can be found in Liljegren et al. (2008).

The model requires meteorological inputs of air temperature, relative humidity, wind speed, global solar radiation, and surface pressure. Outputs include the WBGT as well as wet bulb and globe temperatures. For analysis, we considered exceedance days which include any day where an hourly WBGT > 32.3°C and constructed a 15 yr annual and seasonal climatology of average exceedance day frequency for 217 stations across the contiguous US. The station data were interpolated to a 0.5° × 0.5° grid, which closely matches the 50 km resolution of the climate model output, using a spherical interpolation method adapted from Shepard's Cartesian based algorithm (Willmott et al. 1985).

2.2. NSRDB dataset

Hourly meteorological input data from 1991–2005 were obtained from the National Solar Radiation Database (NSRDB; National Renewable Energy Laboratory 2007) for 217 Class I stations across the contiguous US. We limited our dataset to the Class I stations because these have the most complete period of record of meteorological data and the highest-quality modeled solar data. Wind speed data were collected at 10 m and were adjusted to 2 m using a logarithmic wind profile (Stull 2000).

2.3. Climate models

A 3-member ensemble of high-resolution RCM simulations from the North American Regional Climate Change Assessment Program (NARCCAP; Mearns et al. 2007) was used in this study. One of the motivations of the NARCCAP project is to provide the climate impacts and adaptation community with high-resolution regional climate change scenarios that can be used for studies of the societal impacts of climate change and possible adaptation strategies (Mearns et al. 2007). These model outputs are well suited to a study of this nature because they provide the necessary meteorological variables to calculate the WBGT at a sufficiently high spatial resolution. Because regional climate is modified by the land surface and topography which can have a significant effect on the WBGT, the use of high-resolution data that capture these local climatic details is well justified in a study of this nature. The added value gained by the NARCCAP RCMs compared to the coarser-resolution GCMs in simulating the US climate was demonstrated by Elguindi & Grundstein (2013). The NARCCAP data can be downloaded from www.narccap.ucar.edu.

Information regarding the 3 ensemble members is provided in Table 1. All simulations were run using a 50 km horizontal resolution for 30 yr of the current climate (1971–2000), and 30 yr of the future climate (2041–2070) following the A2 scenario from the Special Report on Emissions Scenarios of the Intergovernmental Panel on Climate Change (Nakicenovic et al. 2000). The WBGT was calculated using 3-hourly data for each individual model, and then an unweighted average was calculated from the 3 models for the final analysis.

Several studies have assessed the performance and biases of the NARCCAP simulations (e.g. Bukovsky 2012, Mearns et al. 2012, Elguindi & Grundstein 2013), and while the models perform reasonably well, they all nonetheless exhibit some degree of bias. To properly evaluate these biases, exceedance days calculated from National Centers for Environmental Prediction (NCEP) reanalysis-driven simulations for the period 1991–2000 from the 2 RCMs (CRCM and HRM3; note that while 3 GCM–RCM combinations are used, there are only 2 different RCMs) were compared to observations (Fig. 1). In assessing model performance, we expect somewhat higher biases than we would find in trying to simulate a single variable like temperature due to the complexity of the WBGT model and requirement for the input of 7 variables at a sub-daily temporal resolution. A key factor in our assessment is that the models are able to reproduce the spatial patterns of exceedance days. Indeed, results show that the ensemble average successfully reproduces the overall spatial pattern reasonably well annually and by season, identifying peak frequencies of extreme heat hazards across the southern tier of the country and along the central valley of California (Fig. 1a–d for observations and Fig. 1e–h for the average model). The magnitude of differences (Fig. 1i–l) for much of the country is relatively small, but more substantial overestimates can be found across portions of Texas and southern California. Since we were mainly interested in the impacts of climate change, and to eliminate the models' systematic biases, we only looked at the change in the WBGT statistics between the historical and future simulations. Therefore, the historical map represents the observations, and the future map is simply the change calculated between the future and historical model simulations added to the historical observations. It should also be noted that this method assumes the biases are similar in the historical and future periods, and only addresses the

Table 1. Regional climate model (RCM) – global circulation model (GCM) ensemble members

Model (resolution)	RCM	GCM
CRCM-CCSM (50 km)	Canadian RCM (CRCM) of the Canadian Centre for Climate Modelling and Analysis (CCCMA)	Community Climate System Model (CCSM) of the National Center for Atmospheric Research (NCAR)
CRCM-CGCM3 (50 km)	CRCM of the CCCMA	Coupled Global Climate Model (CGCM3) of the CCCMA
HRM3-HADCM3 (50 km)	High Resolution Model (HRM3) of the UK's Met Office Hadley Centre	Hadley Climate Model (HADCM3) of the UK's Met Office Hadley Centre

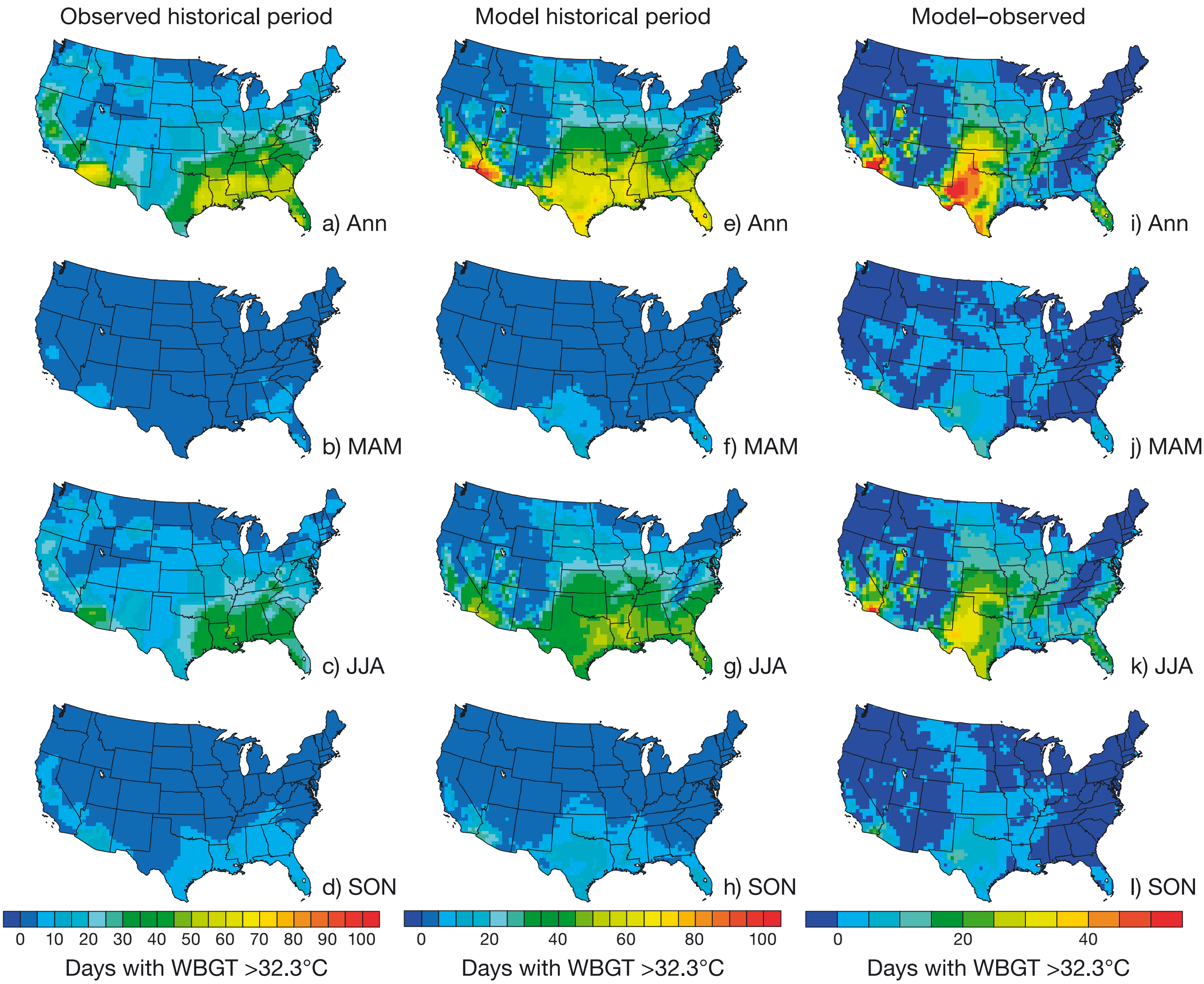

Fig. 1. Average annual frequency of days with wet bulb globe temperature (WBGT) >32.3°C for (a–d) historical period using observations (1991–2000) for annual, spring, summer, and fall, respectively; (e–h) historical period using NCEP-driven regional climate model output (1991–2000) for annual, spring, summer, and fall, respectively; and (i–l) difference in exceedance days (NCEP-model – observed) for annual, spring, summer, and fall, respectively

models' systematic biases. Thus, our approach does not compensate for statistical biases present in the model data. Nevertheless, our results provide a general idea of how the spatial pattern and magnitude of exceedance days may evolve under the projected climate change.

3. RESULTS

Maps of the average frequency of days where WBGT >32.3°C for current conditions (1991–2005) and for a future scenario (2041–2070) assuming a change in climate were constructed by season (spring, summer, fall) and annually (Fig. 2). Present climatology shows a great spatial variation in annual frequency across the contiguous US (Fig. 2a). Few exceedance days, generally ≤5 d yr^{-1}, are present over the northern portions of the country, including the Pacific Northwest, upper Midwest, and New England. The greatest frequencies of exceedance days are across the southern portion of the US, including states along the Gulf Coast and Southeast, as well as southern Arizona. Here, oppressive conditions average at least 30 and >50 d yr^{-1} in some locations. An arc of states from west Texas extending northward into Nebraska and eastward through Ohio average 15–30 exceedance days yr^{-1}. Season-

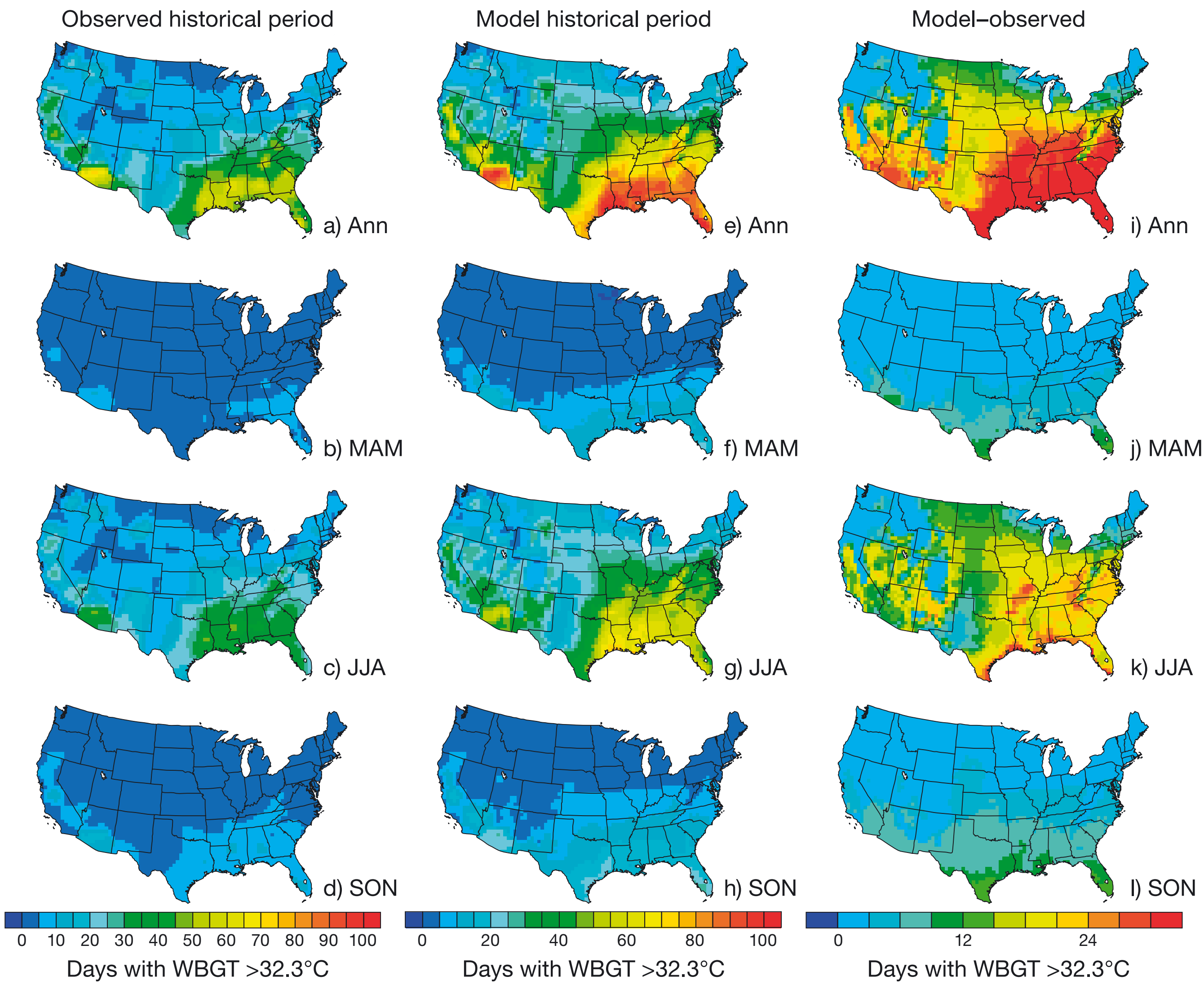

Fig. 2. Average annual frequency of days with wet bulb globe temperature (WBGT) >32.3°C for (a–d) historical period (1991–2005) for annual, spring, summer, and fall, respectively; (e–h) future period (2041–2070) for annual, spring, summer, and fall, respectively; and (i–l) difference in exceedance days (future – present) for annual, spring, summer, and fall, respectively

ally, the vast majority of oppressive days occur in the summer (Fig. 2b–d). Across most of the country, spring and fall have very few exceedance days with approximately 5–15 such days occurring across southern and southwestern portions of the nation (Fig. 2b,d).

Under the climate change scenario, the relative spatial pattern of exceedance days is similar to the historical period, but there is an increased frequency of oppressive days, ranging from 15 to >30 d yr^{-1} across broad swaths of the country (Fig. 2i). Only the Pacific Northwest, northern New England, northern tips of Minnesota, Wisconsin, and Michigan, and the Rocky Mountains show little or no change. Across southern Arizona and states that border the Gulf Coast, >85 d yr^{-1} will have afternoon conditions where practices would need to be cancelled (Fig. 2e). Further, 25–60 d yr^{-1}, i.e. nearly double the present-day conditions, would exceed safety thresholds in an arc extending northward from Texas into South Dakota and eastward through much of the Midwest and Ohio Valley areas. The latitudinal shift in the frequency of oppressive days can be envisioned by noticing that in the future, Missouri and portions of Illinois and Indiana would have similar frequencies of exceedance days as states in the deep south like Alabama and Georgia (Fig. 2a,e). Also, locations in North Dakota and Minnesota, which at present infrequently experience any exceedance days, would have at least 2 wk of oppressive conditions (Fig. 2e).

Seasonally, the greatest increase in oppressive days occurs in the summer months, but increases are also evident in the fall and spring (Fig. 2j–l). During the spring and more notably in the fall, there are 6–12 more exceedance days across the southern US, which constitutes at least a 50% increase in dangerous conditions. An important implication is that the temporal range for oppressive conditions has more widely expanded beyond the summer months.

Finally, we examined the change in frequency of exceedance by time of day for a sample of stations distributed across the country (Table 2). The model data are 3-hourly in GMT while the WBGT climatology is in local time. We opted not to interpolate the 3-hourly values as this would introduce further uncertainty into our modeled WBGT estimates. Thus, we matched up the 3-hourly model output in GMT with the associated WBGT value in local daylight time (LDT) within the climatology. As there are several time zones across the contiguous US, we were not able to provide uniform comparisons at a given time. For instance, GMT 18 corresponds with 14:00 h Eastern Daylight Time, 13:00 h Central Daylight Time, 12:00 h Mountain Daylight Time, and 11:00 h Pacific Daylight Time. Thus, we identified observed and modeled exceedance in days per year for morning (7:00–9:00 h LDT), late morning-noon (10:00–12:00 h LDT), afternoon (13:00–15:00 h LDT), late afternoon-evening (16:00–18:00 h LDT), and evening (19:00–20:00 h LDT) periods. The historical climatology shows that little (≤1 d) or no exceedance values occur during the morning (7:00–9:00 h LDT) or evenings

Table 2. Frequency of exceedance of 32.3°C wet bulb globe temperature (WBGT) in days per year for historical (1991–2005) and future periods by time of day (given as local daylight time). Cities are grouped by time zone, and all values are rounded to nearest whole number

	Morning		Late morning-noon		Afternoon		Late afternoon-evening		Evening	
	8:00 h		11:00 h		14:00 h		17:00 h		20:00 h	
EASTERN	Historical	Future	Historical	Future	Historical	Future	Historical	Future	Historical	Future
Atlanta, GA	0	0	4	19	7	30	3	31	0	15
Boston, MA	0	0	1	2	0	6	0	2	0	0
Gainesville, FL	0	2	12	30	14	34	5	32	0	10
Richmond, VA	0	0	5	16	7	26	2	24	0	5
Indianapolis, IN	0	0	2	12	3	20	1	12	0	0
	7:00 h		10:00 h		13:00 h		16:00 h		19:00 h	
CENTRAL	Historical	Future	Historical	Future	Historical	Future	Historical	Future	Historical	Future
Dallas, TX	0	0	2	28	10	24	11	27	1	24
Huron, SD	0	0	0	3	2	15	2	16	0	12
Kansas City, MO	0	0	1	8	5	21	6	23	1	18
Minneapolis, MN	0	0	0	3	2	13	1	14	0	6
Nashville, TN	0	0	7	21	8	26	3	29	0	20
New Orleans, LA	0	1	8	14	17	36	11	36	0	13
	9:00 h		12:00 h		15:00 h		18:00 h			
WEST	Historical	Future	Historical	Future	Historical	Future	Historical	Future		
Albuquerque, NM	0	0	5	19	4	25	0	5		
Billings, MT	0	0	1	7	1	13	0	6		
Cheyenne, WY	0	0	1	9	0	9	0	1		
Phoenix, AZ	0	0	18	24	26	27	6	21		
Salt Lake City, UT	0	0	2	0	1	6	0	2		
	8:00 h		11:00 h		14:00 h		17:00 h		20:00 h	
PACIFIC	Historical	Future	Historical	Future	Historical	Future	Historical	Future	Historical	Future
Fresno, CA	0	0	7	8	13	22	4	19	0	0
Las Vegas, NV	0	0	9	21	11	22	5	22	0	0
Los Angeles, CA	0	1	1	4	0	3	0	0	0	0
Portland, OR	0	0	0	0	1	3	0	2	0	0
Spokane, WA	0	0	0	1	1	5	1	3	0	0

(19:00–20:00 h LDT). Exceedances increase in the late morning, generally peak in the afternoon (13:00–15:00 h LDT), and decrease through the late afternoon to the evening. Under the forecast warming climate, mornings continue to have little or no likelihood of exceedance. However, late morning through early evening periods reveal substantial increases in the frequency of the extreme heat hazard under climate change. The magnitude of this change varies geographically, with the most substantial changes occurring in the southern half of the country (e.g. Atlanta, Gainesville, Richmond, Dallas, Nashville, New Orleans, Albuquerque, Phoenix, Las Vegas). The frequency of extreme heat in Gainesville, for instance, increases by 18 d at 11:00 h LDT, 20 d at 14:00 h LDT, and 27 d at 17:00 h LDT. Also, at 19:00 h LDT in the Central region (the only region with time matches in this period), there is a shift from virtually no exceedance days to >20 d in some locations. Across the Midwest in places such as Indianapolis, Huron, and Minneapolis, which climatologically have ≤3 d at most in any time period, there will be 13–20 d of extreme heat during the afternoon. Lastly, only modest increases in extreme heat are predicted along the Pacific coast in places like Los Angeles, in the Pacific Northwest (e.g. Portland and Spokane), and Northeast (e.g. Boston).

4. DISCUSSION AND CONCLUSIONS

Expected climate change will lead to a considerable increase in the frequency of days with conditions deemed unsuitable for sports activity across much of the US. Youth athletes, who often practice in the afternoon to coordinate with school schedules, will be particularly affected. The expansion of the seasonal range for oppressive conditions means that in traditional spring sports such as tennis, soccer, track and field, softball, and baseball, which have not traditionally faced frequent extreme heat, conditions will have to be more carefully monitored and athletes acclimatized. Fall sports, particularly football, an equipment intensive sport, will experience more frequent extreme heat during early-season training in the summer and an expansion of oppressive days into autumn. Further, our temporal analysis reveals an increase in the threat for extreme heat through the day ranging from late morning through early evening, although early morning even under a warming climate remains the safest period to avoid extreme heat exposure. A practical implication of these results is that in the future there will be fewer available practice times corresponding with the school day that minimize heat hazards. Thus, more care and planning must be used in scheduling athletic activities.

These conditions, however, do not preclude participation in sporting activities but do indicate the importance of adopting heat illness prevention and pre-season acclimatization policies that will provide guidance for training under hot conditions. Effective plans must provide for acclimatization periods for the athletes as well as require that practices adjust to environmental conditions by varying the level of equipment worn, activity levels, and rest periods (e.g. Bergeron et al. 2005, Casa & Csillan 2009). As mentioned earlier, professional (NFL) and college organizations (NCAA) in the US have adopted strong heat policies, but at present only a few states (e.g. Arizona, Arkansas, Connecticut, Florida, Georgia, Iowa, North Carolina, Texas) have developed effective ones for their youth athletes (Korey Stringer Institute 2013). Unfortunately, this means that most states are unprepared for the increased frequency of extreme heat and the greater hazards for interscholastic athletes. It is hoped that the increased hazard from oppressively hot days forecast under a warming climate will provide support and encouragement for states to adopt heat policies. In addition, schools might consider adaptation strategies like adjusting practice times to climatologically cooler periods such as the morning.

Acknowledgements. We thank Dr. James Liljegren for kindly sharing a copy of his WBGT model and the North American Regional Climate Change Assessment Program (NARCCAP) for providing the climate model output used in this paper.

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Editorial responsibility: Helmut Mayer, Freiburg, Germany

Submitted: February 15, 2013; Accepted: September 23, 2013
Proofs received from author(s): November 27, 2013