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Climate change and occupational health: A South African perspective

T Kjellstrom,[1,2] MME (Stockholm), Med Dr (Stockholm); **B Lemke**,[3] PhD; **O Hyatt**,[1] PhD; **M Otto**,[3] MME

[1] *Health and Environment International Trust, Mapua, New Zealand*
[2] *United Nations University, International Institute of Global Health, Kuala Lumpur, Malaysia*
[3] *Nelson-Marlborough Institute of Technology, Nelson, New Zealand*

Corresponding author: *T Kjellstrom (kjellstromt@yahoo.com)*

A number of aspects of human health are caused by, or associated with, local climate conditions, such as heat and cold, rainfall, wind and cloudiness. Any of these aspects of health can also be affected by climate change, and the predicted higher temperatures, changes in rainfall, and more frequent extreme weather conditions will create increased health risks in many workplaces. Important occupational health risks include heat stress effects, injuries due to extreme weather, increased chemical exposures, vector-borne diseases and under-nutrition. In South Africa (SA), and many other parts of the world experiencing a hot season each year, the effects of heat stress may be of greatest relevance to the large working populations in mining, agriculture, construction, quarries and outdoor services. Factory and workshop heat will also become an increasing problem in the numerous workplaces without effective cooling systems. SA was the location for some of the most detailed research on heat effects at work in mines in the 1950s and 1960s, and the future will bring new challenges not only for mines, but also for many other workplaces. The climate model trends for this century indicate that the heat exposure may increase by 2 - 4°C during the hottest months, and this would change the occupational heat situation from 'low risk' to 'moderate or high risk' in much of SA.

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Climate conditions of special importance to occupational health

Global climate change will create, in many places, higher average atmospheric temperature, changes in rainfall and wind patterns, more extreme weather events, and sea-level rise.[1] The underlying analysis of greenhouse gas emissions focuses on increased thermal energy in the atmosphere and the temperature changes are the most valid estimates. Direct effects on health of thermal conditions are therefore of particular importance. Workplace heat exposure is a well-known occupational health hazard,[2] and local climate change will make risks more widespread and create new risks.[3] Workplace exposure to excessively cold conditions is also a well-known hazard, but only a small fraction of the global population lives and works in very cold locations. Colder places are generally in developed countries where there is usually good access to heating, so the effects of heat at work are therefore more prominent than those of cold. Apart from thermal exposures, which are likely to dominate in many places, several other occupational hazards will be induced by climate change (Table 1).[4,5] Extreme weather events, storms and floods will create injury and drowning risks for emergency workers, as well as for local people exposed at their workplace. Excessive workplace heat is in itself an injury hazard.[6]

Higher daytime temperature will cause people to change their work pattern, making use of the cooler mornings and evenings. In areas where mosquito-borne diseases (e.g. malaria and dengue) are common, changes in work patterns with more work at dawn and dusk can increase the risk of such diseases among agricultural workers.[4] In workplaces where chemical exposures are common (e.g. solvents exposure in factories using glues and paints), the daily exposure to poisonous chemicals may increase as a result of higher evaporation. Agricultural workers may also experience higher exposure to pesticides, as more chemicals are used when insects thrive in hotter conditions, or as the pesticide components evaporate faster at higher temperatures. In addition, climate change causing droughts or floods will jeopardise farm production, and low-income farmers in areas with climate-induced losses in agricultural production may suffer significant under-nutrition and a related reduction in physical work capacity.

As it is likely that increasing heat exposure in the workplace will be the most common and most predictable occupational health impact of climate change in South Africa (SA), as well as in much of the tropical and subtropical regions of the world, this paper focuses on this hazard in this location. Studies of the hazards of workplace heat have a long history in SA. A mining company medical officer, Wyndham, carried out detailed studies of gold mine workers during the 1950s and 1960s.[7] Heat-related mortality and morbidity rates were very high for workers 1 000 metres below ground, but decreased when occupational health management procedures including heat acclimatisation at ground level were implemented. Wyndham[7] also quantified the productivity loss due to heat exposure. These studies continue to provide important quantitative evidence about the heat risks for workers, as no updated studies of the current heat exposure and risk conditions in SA mines have been published.

Other groups with particular risks of dangerous exposures to heat are outdoor workers in agriculture, quarries and construction areas in hot regions.[8] They need to take long breaks during the day ('self-pacing') because of the heat, and hourly productivity is reduced. The most quantitative data from agricultural workers[8] showed a 30% reduction in hourly productivity when the heat level rose by 5°C. Media reports involving construction workers in Qatar, preparing for the 2022 soccer World Cup matches, highlight the very high mortality

Table 1. Potential occupational health hazards related to climate change with hotter and stormier conditions in most of the world

Type of hazard	Examples of vulnerable groups of working people	Potential size of vulnerable groups
Excessive heat at work	Workers in tropical and subtropical areas; outdoor workers in physically demanding jobs (agriculture, construction, quarries, outdoor cleaning workers, rubbish collectors, road building and repair); indoor workers in factories or workshops without air conditioning or other cooling systems (common heat problem in many hot countries); indoor workers in offices without air conditioning (heat stress affects accuracy and productivity)	Several billion people in low- and middle-income tropical and subtropical countries
Excessive cold at work	Outdoor workers in the Arctic or extremely high-altitude areas (because of increasing climate variability, serious cold snaps may increase locally even though annual average temperature rises)	A few million people in cold areas (for most of them reduced cold will occur)
Extreme weather	Emergency workers experiencing heat strain symptoms (increases the need for workers in specific event); workers in various jobs in flooded or storm-ravaged areas; poor people in small-scale home industry or agriculture; people losing all their income or forced to migrate (mental health problems)	A few million each year
Vector-borne diseases	Agricultural workers in areas with changing malaria or dengue patterns	Many millions in low-income areas
Additional chemical exposures	Factory workers in places where glues and solvents are widely used; agricultural workers spraying pesticides	Many millions in low- and middle-income countries
Lack of nutrition	Subsistence farm workers (and their families) in areas where agricultural production is significantly reduced by climate change	Many millions in low- and middle-income countries

rates from heart disease and construction injuries.[9] It is likely that the local heat conditions increased both of these health conditions, but no detailed studies have been published on these risks.

Chronic kidney disease has also been identified as a potential problem among sugar-cane cutters in hot locations in Central America.[10] Results suggest that repeated daily dehydration due to profuse sweating and insufficient rehydration may contribute to kidney disease, although the quantitative risks are still uncertain. Lastly, indoor workplaces in factories and workshops in low- and middle-income countries are seldom cooled by air conditioning (e.g. automotive industries)[11] and heat stress is a common complaint. Heat effects are worse in areas with frequent power cuts because workers do not become acclimatised to the hot conditions while air conditioners are on, and suffer because of extreme changes of temperature.

Quantifying the impacts

The health hazards associated with workplace heat exposure are linked to air temperature and humidity, air movement (wind speed), and heat radiation (outdoors, usually from the sun).[2] Any meaningful heat exposure index should take these into account, and the most commonly used is the wet bulb globe temperature (WBGT) index.[2] It is linked to the human physiological reaction to heat. The body core temperature is 37°C and an air temperature or radiant temperature higher than body core temperature will transfer heat from the environment to the body.

When a person is involved in physical activity (e.g. while working, walking or bicycling), the muscular work creates major heat production inside the body.[2] This needs to be transferred in order to avoid an increase in body core temperature and clinical effects of heat stroke. Evaporation of sweat is a powerful means of transferring heat from the body to the surrounding air, but this evaporation is reduced as the air humidity is increased, and at 100% relative humidity, no net evaporation takes place. Air movement over the skin contributes to the evaporation and heat transfer.[2] The physical and physiological relationships are also influenced by clothing and metabolic rate from physical activity. Various standards and heat stress analyses exist (e.g. the international standard),[12] and approximate WBGT levels can be calculated from weather station data.[5] The different heat stress indexes depend primarily on air temperature and humidity.

In order to describe the local occupational health risks associated with local climate conditions (in particular heat exposures), several approaches to analyse temporal and spatial distributions are available. The weather station data from the US National Oceanographic and Atmospheric Administration (NOAA) stores and makes available over the Internet the hourly and daily recordings from many thousand weather stations around the world in a global summary of the day (GSOD). Special software, Hothaps-Soft, has been developed to enable rapid and user-friendly access to these data (see: www.ClimateCHIP.org).[13] Using this software, the last 30 years of heat exposure data for Cape Town airport are shown in Fig. 1. The fitted linear trend lines show 0.46°C and 0.61°C increase per decade for weather station data and Climate Research Unit ((CRU), University of East Anglia, Norwich, UK) estimates, respectively. These increases of heat levels during the hottest month are higher than the recorded global average, creating concern about future heat stress at work. An additional concern in cities is the 'urban heat island' effect, which means that the local heat conditions can be much hotter than at the local weather station (usually located at an airport). The values are estimated for 'in-full-shade places' (or indoors without cooling) and WBGT levels in the sun during afternoons are likely to be 2 - 3°C higher.[14] A WBGT level at 26°C creates difficulties for continuous work at high work intensity.[12]

Another place with detailed data available is East London in the Eastern Cape, SA. Here, the fitted linear trends for February are at 0.28°C and 0.34°C increase per decade for weather station and CRU grid cell data, respectively. Hothaps-Soft outputs can also describe the monthly means and distributions of different climate variables. Fig. 2 shows the ranges of actual daily data of 'in-shade WBGTmax' (percentiles for 10, 25, 75 and 90% of days) for the first 10 years of this century in Cape Town and East London. The individual values beyond the 10th and 90th percentiles are also shown, and in the

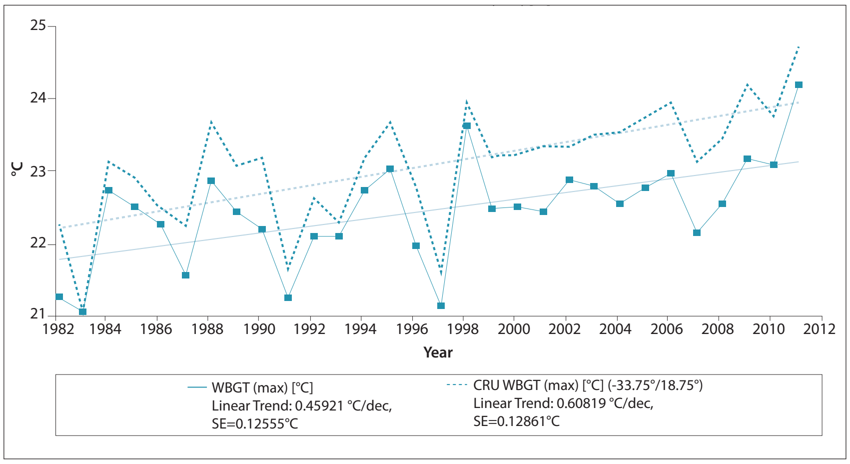

Fig. 1. February monthly averages of in-shade WBGTmax (afternoon values) for Cape Town international airport, annual data and regression lines. Solid annual curve and regression line are based on temperature and humidity data from the weather station (point location, NOAA/GSOD), while the dotted annual curve and regression line are the equivalent data for the geographic grid cell (approximately 50 x 50 km) where the weather station is located (grid cell data from CRU, University of East Anglia, Norwich, UK). Source: Hothaps-Soft output (http://www.ClimateCHIP.org).[13] (WBGTmax = wet bulb globe temperature maximum; NOAA/GSOD = National Oceanographic and Atmospheric Administration global summary of the day.)

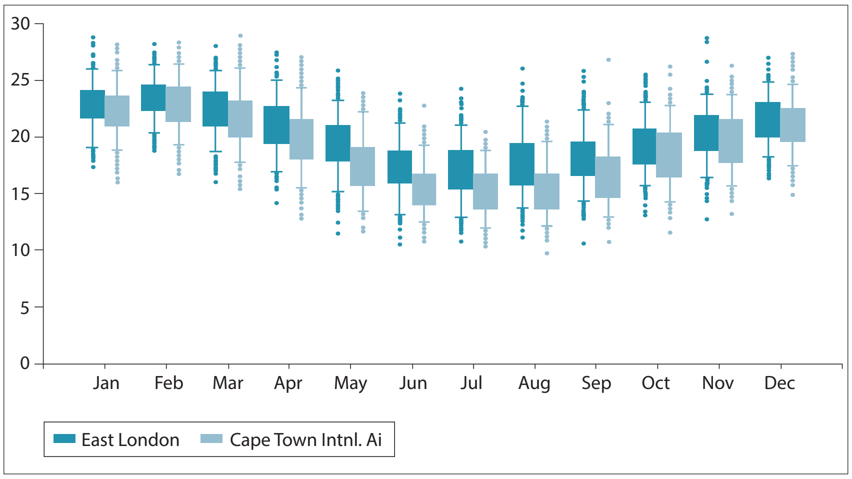

Fig. 2. Monthly averages and 25th and 10th percentiles of daily data on WBGTmax in shade calculated from weather station data for the first decade of this century in Cape Town and East London. Source: Hothaps-Soft output (http://www.ClimateCHIP.org).[13]

hottest months these rise to 28 - 29°C, which is a very high and restricting heat level for workers (also note that 'in-sun levels' can be 2 - 3°C higher).[14] The website www.ClimateCHIP.org makes it possible to analyse the time trends for CRU data for any grid cell in SA, and Hothaps-Soft analysis makes it possible to study time trends and other descriptive analysis for any weather station in the GSOD system.

The most common impact of heat exposures on occupational health in the workplace is likely to be the reduction of work capacity due to 'self-pacing' in hot jobs. A detailed report for the World Health Organization (WHO) contains estimates of the risk functions for three different metabolic rate levels (Fig. 3).[13] Approximately 20% of the work capacity is lost at a WBGT of 28°C, 30°C and 32°C for heavy, moderate and light labour, respectively.

At the current heat exposure levels in the shade in Cape Town and East London, only a few days in each of the hottest months are reaching these levels, but with the additional 2 - 3°C of WBGT outdoors in the sun, such high levels already occur (90-percentile in both places close to 30°C; Fig. 2). Research quantifying the work capacity loss or health risks in SA has not yet been carried out, but it is now possible, with the growing access to data on local climate conditions and precise risk functions, to make valid, quantitative analyses.

An approximate calculation of the health and economic impacts of current and future (i.e. 2030) climate conditions in SA and all other countries was published in the Climate Vulnerability Monitor 2012.[15] It used the type of methodology referred to above (but with approximate climate and risk function estimates) and concluded that the cost of labour productivity loss due to excessive heat in workplaces was US$1.250 million PPP (Purchasing Power Parity dollars) in 2010, and likely to increase to US$7.250 million in 2030. The climate vulnerability analysis[15] also shows the increase in mortality due to diarrhoeal diseases and hunger, as well as a number of other economic impacts of climate change. An updated and improved analysis is planned for 2015 by the Climate Vulnerable Forum, a group of 20 low- and middle-income countries where major negative impacts of climate change are expected, but with minimal contribution to global greenhouse gas emissions (http://www.thecvf.org/).

The tools to calculate current and future climate conditions at the local level are continually being improved. Hothaps-Soft can produce detailed user-friendly tables and graphics from weather stations and grid cells anywhere in the world. Research in SA and other countries could benefit greatly from testing these new sources of information and calculation methods. The starting point should always be the occupational health hazards related to climate conditions already in existence, and, from these, estimates of the future risks and trends can be developed.

Future projections for SA

The impact of climate change in SA has become an important political issue as the country is part of the five key BRICS countries (Brazil, Russia, India, China, SA), which contain almost half of the world's population and which have major, ongoing economic development. Such development is likely to slow as the climate gets hotter. SA's national Climate Change Response Policy[16] aims at a 'socio-economic transition to a climate-resilient and low-carbon economy and society'. It requires a 'balance between efforts to reduce greenhouse gases (mitigation) and efforts to build resilience to the impacts of climate change (adaption)'. The occupational health and productivity

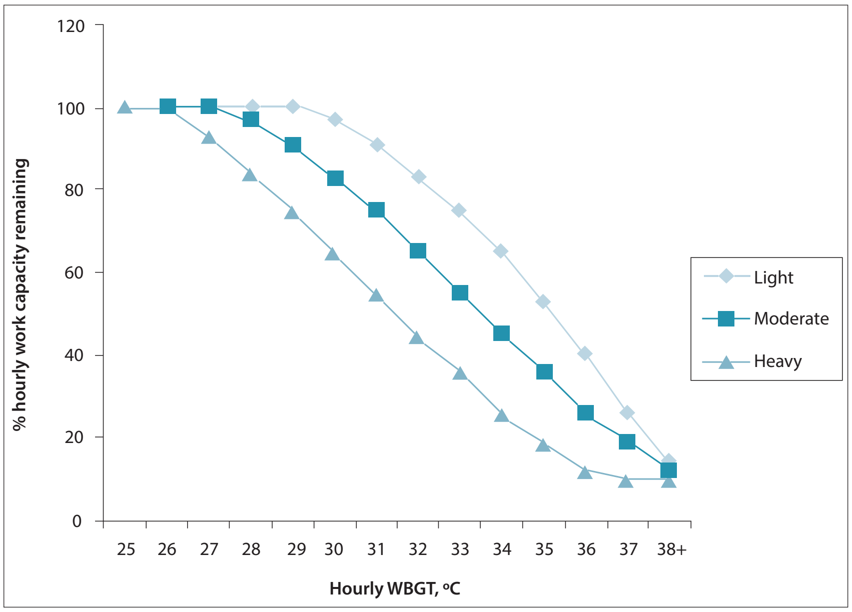

Fig. 3. Estimated exposure-response risk functions for workplace heat exposure and work capacity loss, based on data from Wyndham[7] for moderate labour and the difference in risk for light and heavy labour as expressed by ISO.[12] Source: http://www.ClimateCHIP.org.[13]

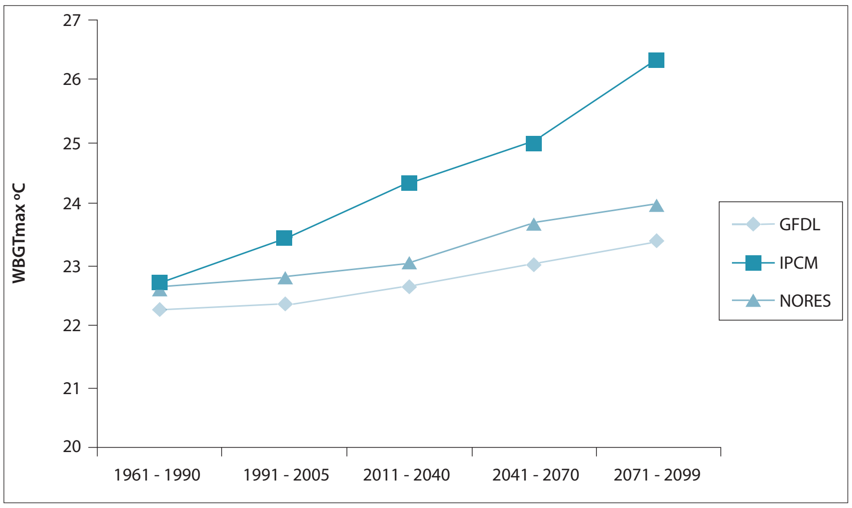

Fig. 4. Trends of climate model data for the grid cell at East London in February at five time points (25 - 30-year averages). Three of the internationally agreed models: GFDL, IPCM and NORES (described in IPCC Working Group 1 report).[1] (GFDL = Geophysical Fluid Dynamics Laboratory model (USA); IPCM = Institute Pierre Simon Laplace model (France); NORES = Norwegian Earth System model.)

threats from climate change need to be considered in this 'transition'. Climate modelling data already indicate the trends. Fig. 4 shows results for three future models at the RCP 6.0 'pathway' (RCP = representative concentration pathways; RCP 6.0 is one of four pathways for future greenhouse gas emission developments, and not the most extreme one, and assumes that radiative forcing is stabilised at 6 W/m^2 after 2100). In East London, this RCP produces increased WBGTmax in February as shown in Fig. 4: 1.5°C increase in 2085 for two models and almost 4°C for the third model.

Another way of presenting future projections is the mapping of WBGT values (Fig. 5). The projections of a 3°C increase in afternoon heat levels in the shade would bring most of SA into the 'moderate to high risk' heat category for the hotter months of the year. Some parts of SA remain at levels below 26°C, and these are primarily high-altitude areas with cooler temperatures all year round.

The hottest time of the year (i.e. summer months of December, January and February) is already a workplace heat challenge and a variety of symptoms are reported by workers exposed to high heat at work.[18] Further analysis of the spatial and temporal workplace heat situation in SA would be of great importance for the development of effective prevention programmes.

Prevention and control

The heat resilience of vulnerable groups of working people can be addressed with the knowledge available, but it needs to be based on the context of the conditions of each group. Mine workers are still a most important group for heat impact prevention, as are many agricultural workers, construction workers and workers in small workshops without cooling systems. Cooling systems include basic air conditioning and design of workplace buildings to reduce heat exposure from outside.

As mentioned above, workers exposed to excessive heat will lose hourly productivity and this is an important cost. Ensuring that sufficient cooling is provided may in fact save more money than the cooling costs. Further proposals for preventive approaches in workplaces can be found on the website http://www.ClimateCHIP.org.[13]

Prevention also means that occupational health services should be available in all workplaces with heat risks. This includes easy access to safe drinking water, 'buddy system' to observe any symptoms of overheating among coworkers, access to medical attention for heat illness, and training of workers and supervisors about all aspects of heat impact prevention.

These basic occupational health prevention actions should be part of the 'normal' facilities and actions by the employer at all workplaces. Any costs need to be integrated into the routine production cost.

In addition to the various preventive approaches to local heat exposure reduction and prevention of health risks, it is important to note that limitation of the ongoing global climate change is a key method to protect future generations of workers from any growing climate-related risks.

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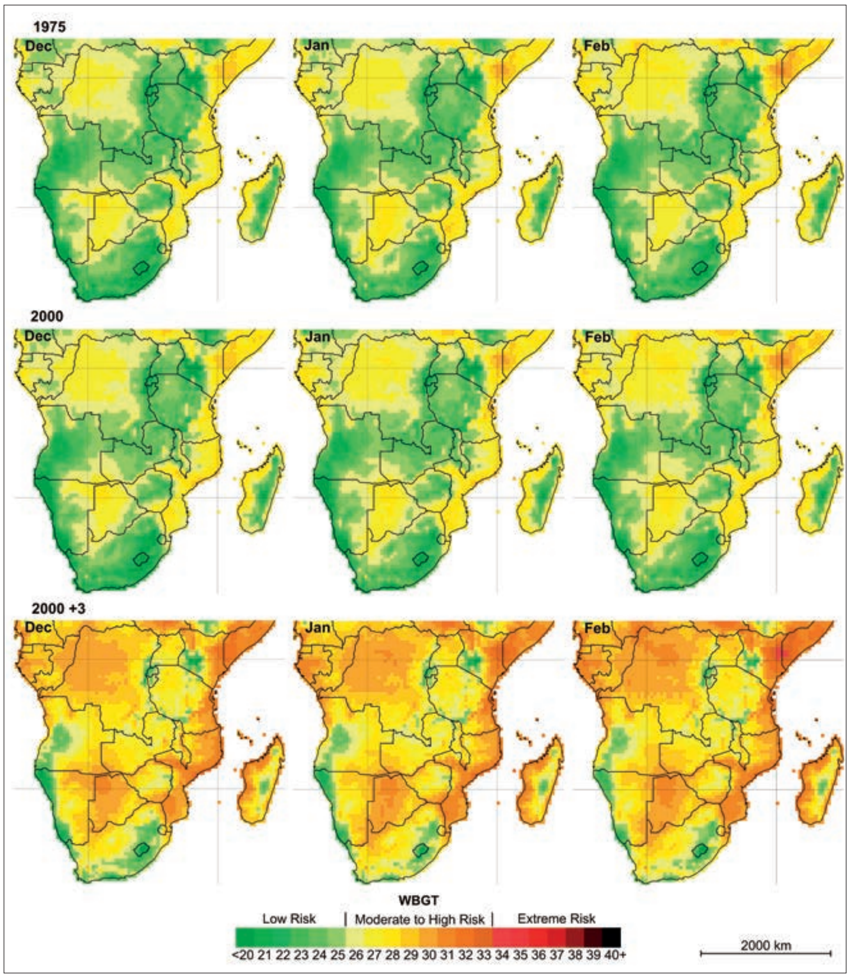

Fig. 5. Map of WBGT heat stress levels (afternoon in-shade or indoors) in southern Africa for the three hottest months in 1975 and 2000 (30-year averages), and after 3°C has been added to the 2000 values.[17]

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