A PODIUM TOO FAR

How climate change will impact sports in Brazil

Executive summary

SPORT IN BRAZIL WILL NEVER BE THE SAME AGAIN AFTER CLIMATE CHANGE*. The amount of warming that is predicted for the country over the coming decades will make it more difficult to break records in several modalities and will frequently pose life risk to athletes. Adaptation to high temperatures will demand more attention and the use of health technologies in all stages of competitions – which will have to occur in alternative hours, such as dawn.*

Between 2070 and 2099, severe temperature elevations in the worst-case emissions scenario (in which either the Paris Agreement commitments are not met or their ambition is not increased) will impose restrictions to sports practice in **12 BRAZILIAN CAPITAL CITIES DURING SEVERAL TIMES OF THE YEAR.** In that scenario, 23 capital cities will suffer strong or very strong heat stress year-round.

In the city of MANAUS IT WILL BE IMPOSSIBLE TO PRACTICE SPORTS OUTDOORS ANY TIME OF THE YEAR. Wet-bulb globe temperatures there will be permanently above 32ºC, the "stop-play" condition as defined by FIFA. The human tolerance limit is a wet-bulb temperature of 35ºC.

Temperature elevations imply in LOSS OF EXCELLENCE IN SPORTS PRACTICE. What fans are likely to see in the coming years are matches or races in which athletes give in to fatigue earlier on, even if they remain in the competition until the end. Such fatigue won't happen only because of the cardiovascular response, but because of neuromuscular response as well. Excess heat leads to a loss of strength and less precise movements.

EVEN TODAY BRAZIL ALREADY EXPERIENCES EXTREME HEAT HAMPERING SPORTS TOURNAMENTS: in the 2014 World Cup, two matches needed technical time when wet bulb temperatures reached 32ºC in the stadiums (in Fortaleza and Manaus); in 2015, a Women's League football match needed to be halted in Piauí after nine players suffered heat-related injuries. In the test events for the Rio Olympics, several athletes had heat-related injuries – in the racewalking competition, 11 out of 18 succumbed to conditions and one passed out.

In the Rio Games there probably will be no records being broken in several modalities. In the Olympic marathon, for instance, no records are broken in places with temperatures above 12ºC. Rio's winter is unlikely to boast such cool conditions.

Global warming already leads sports physicians worldwide to discuss the BEST STRATEGIES FOR COPING WITH HEAT STRESS IN ATHLETES. The debate goes around, for instance previously chilling the body, through fans or even ice.

As an adaptation measure, athletics competitions IN RIO WILL ONLY HAPPEN IN THE MORNINGS AND LATE AFTERNOONS, and soccer matches in Manaus were scheduled for the evenings.

A HOTTER CLIMATE IS ALSO LIKELY TO WIDEN THE INEQUALITIES THAT ARE SEEN TODAY IN HIGH-PERFORMANCE SPORTS. *Adaptation will require more and more high-tech, high-price clothes and other equipment, which are outside the reach of low-income young people, who face barriers already today to enter the career. An active search of new talent needs to be implemented as a measure of adaptation of Brazilian sport.*

Index

Chapter 1:
Climate and health: The new rules of the game
Pág. 4

Chapter 2:
Impacts: today
Heat and sports: a troubled relationship
Pág. 14

Chapter 3:
Impacts: tomorrow
Brazil's new climate
Pág. 20

Expediente

Research and texts:
Lúcia Helena de Oliveira, Wagner Prado and Claudio Angelo

Edition:
Claudio Angelo

Design:
Daniela Fontinele

Infographic:
Estúdio Labirinto

A report by Observatório do Clima

THE NEW RULES OF THE GAME

The test events for Rio2016 were more than just trial run to check the structure and organization of the Olympic Games. The athletes themselves also got a taste of what it will be like to face one of their worst opponents: global warming. As early on as the triathlon test, the Rio de Janeiro winter surprised those who have not been keeping tabs on changes to our climate. The triathlon was the second of 44 competitions programmed between August last year and this May, a series of events ironically called Aquece Rio (Warming Up Rio).

In the height of August, the same month that the actual Olympics take place, triathletes in the men's tests set off at 2pm in nearly 35ºC heat with a relative humidity of 70%. At that moment, the Rio2016 Organizing Committee Medical Director, João Grangeiro Neto, admits that he was concerned about the risk of hyperthermia (elevated body temperature) in the athletes, which can set off a cascade of dangerous and at times fatal physiological reactions. According to him, luckily everything ended well. Some adjustments were made, such as more cooling stations for the athletes throughout the course and rearranging the times of the Games, to place less trust in the idea that they supposedly take part during the "coldest season of the year".

Hot and humid air continued to punish athletes throughout the test events. In the race-walking test, held one weekend in February with 41% humidity and with temperatures reaching 38ºC, 11 of the 18 participants succumbed to the conditions. These included four Brazilians - one of them, Samir Sabadin, fainted and was taken away in an ambulance. He awoke in a state of total mental confusion. The marathon, the ultimate test, took place in an April in which thermometers were reading between 32ºC and 34ºC. Victory lay with Márcio Barreto da Silva from Bahia, who completed in 2 hours, 31 minutes and 22 seconds. For this sport's standards, this time is much slower than the 2 hours and 19 minutes Barreto da Silva himself made when he secured one of Brazil's three places in the event. He is sure that the heat in Rio de Janeiro is the greatest obstacle for the 80 marathon runners fighting for the gold.

The test events give us an idea of what sport will be like from now on: a practice that, due to climate change, will frequently put the life of the athlete at risk, requiring much more attention to and technology surrounding health and thermal adaptation before, during and after competitions. Training and competitions will have to take place at restricted and alternative times, such as early in the morning. And, even doing all of this, com-

Increasing temperatures will force trainings and competitions to take place at alternate schedules, such as night time and dawn

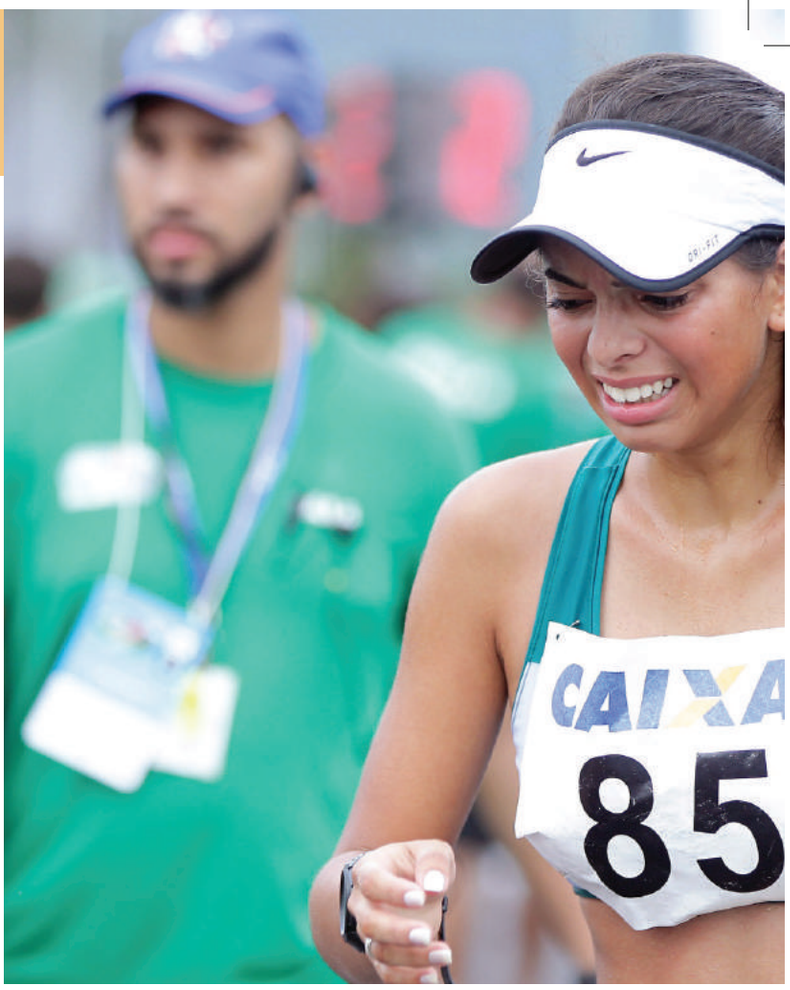
Roberto Castro/Ministério do Esporte

petitions are likely to become slower, with a proliferation of technical errors and difficulty in breaking records. Because of global warming, sport will never be the same again. Particularly in tropical countries, like Brazil, where athletes today have less access to adaptation technologies.

Human beings are homeothermal animals. Their bodies try to maintain a constant internal temperature, as close as possible to 37ºC. It is within this range that the thousands of chemical reactions that take place every moment within our bodies are most efficient. Cooling or heating is, for our bodies, something that hampers its physiology. This limit cannot be extended except for relatively short periods of time.

Faced with this, to guarantee survival, the body has four thermoregulation mechanisms, which either hold on to or dissipate heat generated by our own metabolism, sweating being the principal mechanism (see the infographic on page 12). But the efficiency of these mechanisms depends on the external climate. And they also have limits - these are most restrictive for children and the elderly, for example, and often impractical for athletes in a sport that requires endurance, particularly if performed outdoors, on hot and humid days.

If our thermoregulation mechanisms cannot handle the high temperatures, heat-related illnesses occur. This is the name attributed by science to the consequences of ther-

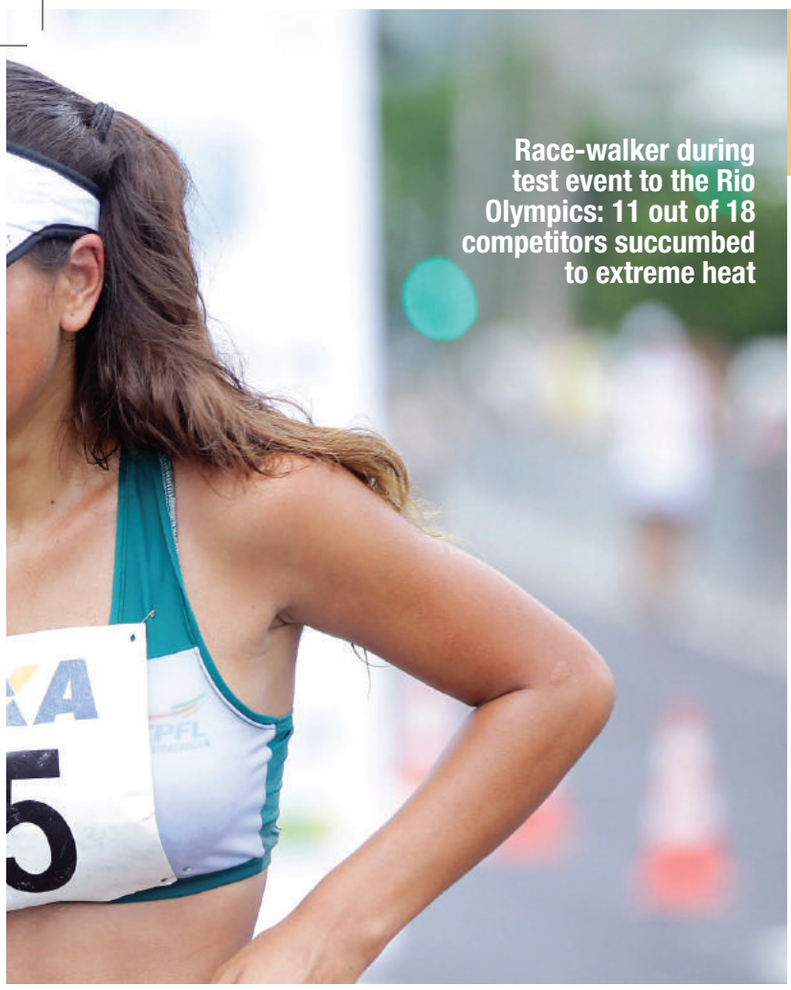


mal stress caused by the overheating of the body, according to exercise physiologist Orlando Laitano, professor at the Vale do São Francisco University, in Pernambuco, and researcher at Florida University, in the USA. He justifies the nomenclature: excessive heat is an agent that causes an immune system reaction similar to that when the body is attacked by virus or harmful bacteria. Furthermore, in this case, the reaction tends to be even quicker and more intense. The symptoms of heatstroke - the most serious heat-related illness - are equivalent to those of sepsis, a generalized infection. For this reason, it can kill quickly.

Among those most likely to suffer heatstroke are sportsmen and women. The explanation can be found in the concept of mechanical efficiency: muscular fibres only transform 5% to 25% of the energy that they obtain into movement. The rest is expelled as heat. The highest energy efficiency levels - between 22% and 25% - corresponds to the metabolism of a professional athlete, according to the calculations of physiologist Paulo Zogaib, sports medicine professor at the Federal University of São Paulo. However, although the muscles of high-performance athletes waste less energy as heat, they also need huge quantities of energy for each training session or competition. That is, when practising sport, the muscles of an Olympic marathon runner become powerful internal heaters - producing a large amount of heat in a short period of time - and their bodies need to compensate for this. But the warming of the planet is making this mission much more difficult.

The duration of the exercise on a hot day, or worse, hot and very humid, makes a difference. Sodium is a chemical element that drains from the body in sweat. There are no records of hyponatraemia - low sodium concentration in the blood - in, for example, 100 m races. However, episodes of this become increasingly more frequent in the sports that require endurance - triathlons, marathons, football and all field sports, tennis and even wrestling and other court team sports after exceeding the 30-minute effort barrier in elevated wet-bulb temperature conditions, a measure that considers the relationship between heat and humidity (see page 22). This is where the athlete's body enters into a vicious cycle.

According to Zogaib, from the moment in which the apparent temperature becomes equal to the body's temperature, sweat production intensifies and, even so, it cannot cool the body - this issue worsens with increased relative humidity. Profuse sweat



Race-walker during test event to the Rio Olympics: 11 out of 18 competitors succumbed to extreme heat

Ivo Lima/Ministério do Esporte

HEATSTROKE

Name given to the most serious form of heat-related illness, which may cause the total collapse of the organism and result in death

WET-BULB TEMPERATURE

Measurement of temperature which takes into account factors such as heat and relative humidity to estimate the amount of effort that a human being can make

sits on the skin, without evaporating. Then comes fatigue and mechanical efficiency drops from 25% to around 20%. Result: muscles start to release 80% of the energy obtained as heat, which aggravates the hyperthermia. Fatigue increases, reducing the muscle's efficiency. The body then heats up a bit more, mechanical efficiency suffers another drop. If the competition is not suspended, it may end badly.

A long time before this point, the nervous system is crying out with thirst. The main ingredient of sweat is liquid removed from blood circulation. And just a small drop in hydration levels - between 2% and 3% of body fluid weight - is enough for the brain suffer. Antonio Herbet Lancha Júnior, professor at the School of Physical Education and Sport at the University of São Paulo (USP), observes that, in volleyball players, this drop is enough to interrupt concentration, increase decision-making time and also body reaction time. Result: a greater number of bad plays. Sports that require extremely accurate movements lose points. This is observed even in sports such as shooting sport, in which hydration was not such a concern in physical preparation.

In research looking at football, Orlando Laitano says that referees suffer similar effects related to liquids and cognitive capacity. Research indicates that heat and the subsequent loss of bodily fluids are related to errors in refereeing. There are also studies that confirm - as revealed by Paulo Zogaib - that, when sweat increases too much, individuals suffer distorted time and space perception. Football players and also the referee stop viewing the ball as they should, losing the notion of the exact direction which it is coming from and calculating its speed badly. All this translates, in the eyes of the fan, into a less-pleasing sport, as if heat reduces the possibility of beautiful plays.

The problem worsens when the volume of blood falls too much, when too much water is removed from circulation for sweat. As there appears to be too little to supply the active muscles and, at the same time, supply

the demanding central nervous system, it is as if the latter gets confused and allows the sweating system to extract water from another source – in this case, from inside cells. The cells therefore continue to shrink until they die - neurons in the frontline platoon. This scenario is, the majority of the time, irreversible, and, ironically, the facts suggest that high-performance athletes are the main characters when history deals this hand. This is because the majority of people feel sick and lose consciousness when the volume of bodily fluid falls by around 6% (dehydration), while sportspeople ignore the systems, either because their bodies are really more resistant to this state, or for more subjective reasons, such as forcing their physiological limits to not give up on a medal.

The threat is no less in swimming competitions held in open water, without the temperature controls of swimming pools. Some time ago, the triathlon recorded a relatively high incidence of deaths compared to other sports. What has been particularly interesting to scientists is that the majority of these do not occur during the land stages - of cycling and running -, but during the first 4 km of swimming. Before, drowning was thought to be the primary cause. Nowadays, however, we know that heatstroke in open water was previously underestimated. Recently, the International Swimming Federation banned official competitions from taking place when the water is equal to or exceeds 31ºC, which is our average peripheral temperature. This is because the human body depends entirely on the conduction of heat from the skin through the medium of water as a form of thermoregulation. If the body is submerged, sweating has no effect. So much so that high performance swimmers tend to

GENETICALLY ADAPTED?

It has been speculated that African marathon runners may have some sort of genetic mutation that makes them more resistant to excessive heat. However, after having combed through the DNA of more than 200 African athletes, nothing different was identified. No portion of human DNA, from the 2,445 genes that interact with physical training, is able to relieve the body of heat. Rodrigo Dias, researcher at the Functional Genomics Laboratory at the Heart Institute of the São Paulo Clinical Hospital, concluded that this was a physiological adaptation phenomenon in which the body adapts to the environment in which it grew up. Just as swimmers tend to present sweat gland atrophy, it is possible that athletes born and raised in hot places on the planet produce, for example, more diluted sweat, without losing so many salts.

The cases of death in open-water swimming have caused the internationsl swimming federation to forbid official competitions when water temperatures touch 31ºC

end up with sweat gland atrophy and, if they perform physical activity on land, can easily succumb to hyperthermia.

The training of athletes has focused for a long time on their capacity to adapt. They land in competition locations a few days beforehand precisely to give their bodies the chance to acclimatize.This is routine. What's new is that increasing heat is demanding that top athletes travel further and more frequently to train for various weeks in countries with a similar climate to that of the climate in which a large competition will take place. This is when they do not resort to exhausting training in chambers, such as those that exist in the Federal University of Minas Gerais (UFMG). There, closed in a 4 m by 4.4 m space, ten athletes pedal away or a group of up to five of them run on the treadmill, with the humidity regulated as required and a temperature that can range from 5ºC to 60ºC.

Alex Ferro/Rio2016

Emerson Silami Garcia is a physiologist, retired from UFMG and visiting professor at the Federal University of Maranhão. According to him, to prepare for a game in the Brazilian climate, in general the chamber temperature is regulated at 45ºC, which is unbearable for the first four days of sweating. The recommendation is to exercise in this sauna-like chamber for two hours a day, for two weeks. This is the intensity of training that the body needs to learn to increase the heart rate more slowly and, at the same time, to start to sweat (and therefore cool) earlier, also producing a sweat lower in salts. All of this helps to delay the appearance of heat-related symptoms.

Scientists are also looking for possible solutions to mitigate the ill effects on the body during competitions. Garcia recently tested an ice helmet that may form part of the uniform for sports such as athletics. This is useful, of course, to cool the head, which is well equipped with blood vessels. The goal, however, is to trick the hypothalamus, the area of the brain that at times serves as the human body's thermostat. This would then identify the drop in body temperature, reducing the sensation of fatigue. Investigation into the use of the helmet brings up a crucial argument: to what extent would this tool to trick the hypothalamus do any good, when the body continues to endure heat from the neck down.

According to specialists, looking at the thermometers, questions like this will become increasingly common in the sporting world. And not only to change the time or delay

competitions, but also to look at the ideal climate for each sport and, more importantly, for each athlete.

Sports science is moving towards customization. Laitano himself is behind the so-called “smart bottle”, which he developed as a consultant at the Gatorade Sports Science Institute. It was tested for the first time by the Brazilian national football team in the 2014 World Cup and should be launched in 2018. The scientist analysed the composition of each athlete’s sweat. Flavour was added to the personal and non-transferable mix of salts and everything was put into capsules like those for espresso coffee. Thanks to a chip, the bottle lid informs the technical team how many sips each player has taken and if it is necessary to adjust the rehydration plan. Another piece of equipment being tested follows the same logic: a drink dispensing machine which scans the athlete’s hand, analyses the sweat composition data taking the wet-bulb temperature and training intensity into account. And there you have it: a made-to-measure isotonic is served.

It is encouraging to see that sports science is preparing to tackle hot times. What is discouraging is to know that this may all just have a palliative effect. The customized isotonic will improve the physical condition of a marathon runner, for example. However, by gastric evacuation rate limits, around 1 litre per hour, the athlete will not be able to replenish the 2 to 3 litres of sweat that s/he is likely to lose in this same time period, if the wet-bulb temperature reaches 32°C. This is all without considering how expensive this equipment is. What now are luxuries will become necessary safety assurance tools. This tends to increase the social gap impeding lower classes from accessing sport. This is particularly marked in Brazil, where few have access to clubs; there are no policies to scout for new talents, or to stimulate sport by means of university access opportunities, such as in the United States.

And it will not be necessary for the planet to reach dangerously high levels of warming for heat to cause problems for the Games. In the Rio2016 Olympic Games, it’s unlikely that there will be records in many sports. The marathon is an excellent example. We know that marathon runners perform best at between 8°C and 11°C; no records have been set in places with temperatures above 12°C along any stretch of the 42.195 km of official track for the Olympic competition. It is also highly unlikely that Rio de Janeiro will provide such cool conditions.

Performance, however, is only one side of the coin. The main damage that climate does to sport is by dissociating it with health.

Adaptation will require technologies that are increasingly sophisticated and expensive, making it harder for low-income athletes to join the sports elite

Mathilde Molla/Rio2016

Even today. A specialist in adapted physical exercise, Luzimar Teixeira, from the School of Physical Education and Sports at USP, is concerned about air pollution, which often originates from the same place as global warming - burning fossil fuels. This is because respiratory volume increases during exercise activity, particularly when it is hot. Consequently, the athlete may inhale more sulphur dioxide, particularly the fine particulates and other compounds that cause immediate damage to lungs.

The researcher takes a pessimistic view in which he sees a relatively young generation of athletes with severe respiratory problems, reminiscent of work-related diseases. Sarcastically, he warns that on hot days in polluted areas, it is healthier to go out and have a beer (in the shade) than to practise sport outdoors. Renata Nakata Teixeira, from the Medical Faculty at the USP, performs research into bronchospasms, breathing difficulties experienced by athletes in endurance sports during competitions. Athletes who suffer these are afterwards more prone to developing asthma. According to her, the medical literature indicates that there are more records of broncospasms in competitions held in excessively high temperatures.

Among the paradoxes of an overheated world, is the discovery published by Orlando Laitano this February: striated skeletal muscle - the one which is attached to bones by tendons and is responsible for voluntary movements -has an endocrine function. It secretes chemical messengers, myokines (muscular cytokines) which interact with the immune system and a number of organs, protecting the organism from the acute effects of heat. However, only well prepared muscle secretes these substances. If the muscle is not in a suitable, athletic condition, it will do the opposite: muscles secrete pro-inflammatory agents which can lead to death by heatstroke. Which comes to the question made by the scientist: it is feasible to have muscles that are extremely well prepared for this climate?

> *“On hot days in polluted areas, it is healthier to go out and have a beer (in the shade) than to practise sport outdoors.*
>
> Luzimar Teixeira, professor at the School of Physical Education and Sport, University of São Paulo

How extreme heat hampers an athlete´s performance

UNDER NORMAL CONDITIONS OF TEMPERATURE AND...

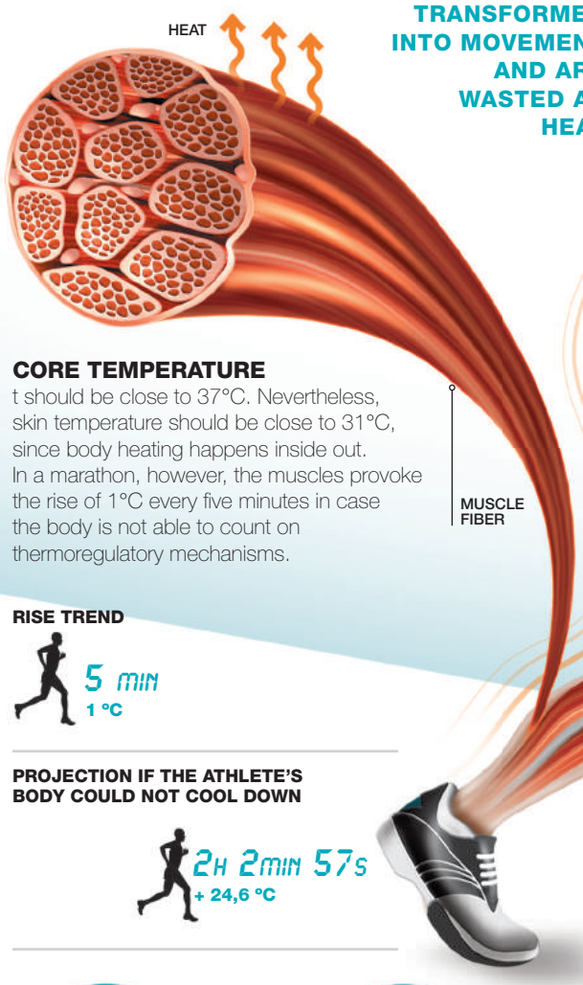
Due to the duration of the race, the marathon is parameter in studies of thermoregulation

MUSCLES GENERATE HEAT

When they contract, the fibres of the skeletal muscles, responsible for the voluntary movements of the body, always eliminate heat. In high performance sports, this release increases up to 25 times and the musculature becomes a p aowerful heater.

3/4

OF THE HUGE AMOUNT OF ENERGY THAT THE ATHLETE'S MUSCLES USE TO RUN ARE NOT TRANSFORMED INTO MOVEMENT AND ARE WASTED AS HEAT



CORE TEMPERATURE

t should be close to 37°C. Nevertheless, skin temperature should be close to 31°C, since body heating happens inside out. In a marathon, however, the muscles provoke the rise of 1°C every five minutes in case the body is not able to count on thermoregulatory mechanisms.

RISE TREND

5 min
1 °C

PROJECTION IF THE ATHLETE'S BODY COULD NOT COOL DOWN

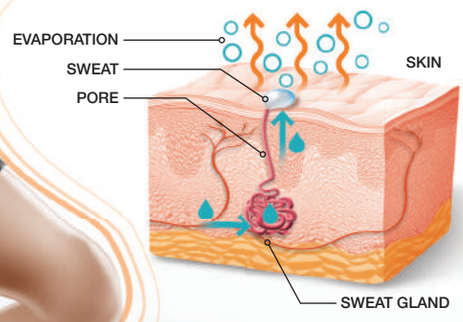
2h 2min 57s
+ 24,6 °C

THROUGH THE AIR

When the runner expires, if the external temperature is lower than that of his body, he loses up to 15% of the excess heat produced by the muscles through conduction and other 3% through evaporation.

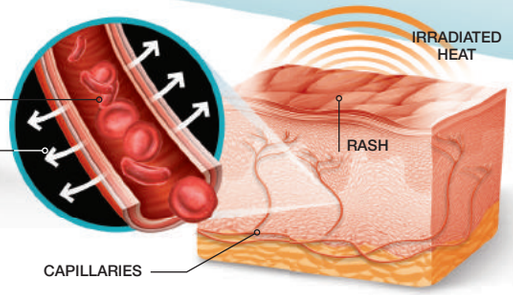
THROUGH SWEAT

The nervous system commands the sweat glands to increase the production of this fluid that, while evaporating, cools the body. Indeed, it is the only outflow for the heat if the environment temperature is equal to or higher than the internal.



THROUGH IRRADIATION

The skin capillaries dilate, conducting heat to the surface. Thus, 60% of the exceeding temperature generated by active muscles are released as infrared rays. That is, in a race in mild climate.



DISTRIBUTION PROBLEM

With the cerebral order for circulation to privilege skin in order to cool the body, the muscles under intense activity complain about the lack of blood supply through chemical signals.

ACCELERATED HEART

It is one of the body's responses, in addition to closing and opening several smaller vessels, to normalize circulation in the active muscles, while conducting heat to the surface.

RAPID BREATHING

The breathing rhythm increases to follow heart acceleration, oxygenating the blood. However, it does not significantly increase heat loss through the exhaled air.

ENVIRONMENT TEMPERATURE ON PERFORMANCE

24°C performance falls 25% or more

11°C maximum performance of any individual in this sport.

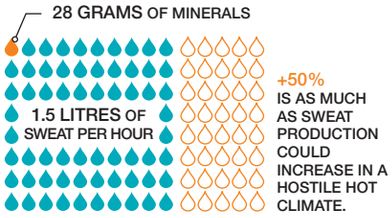
4°C the performance of marathonist also falls 25%

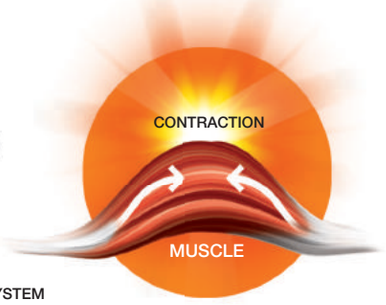
...WHEN THE WEATHER HEATS UP AND BECOMES DAMP

If the thermal sensation is equal to body temperature, the sport could become risky.

SINGLE ALTERNATIVE

Under these conditions, irradiation and conduction cease to take effect. The nervous system uses the mechanism that is left to survive the heat: sweating. The marathoner already loses 1.5 litres of sweat per hour.



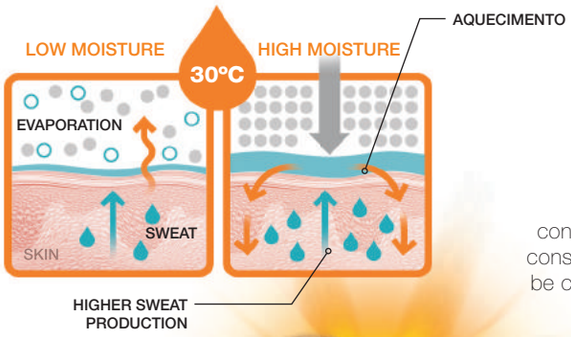


IMPAIRED MOVEMENTS AND CONTRACTIONS

The communication between the nervous system and the muscles loses efficiency. Movements become uncoordinated and slow. There is also loss of strength and painful contractions because of the lack of sodium and potassium through sweat. The runner might fall to the ground from exhaustion.

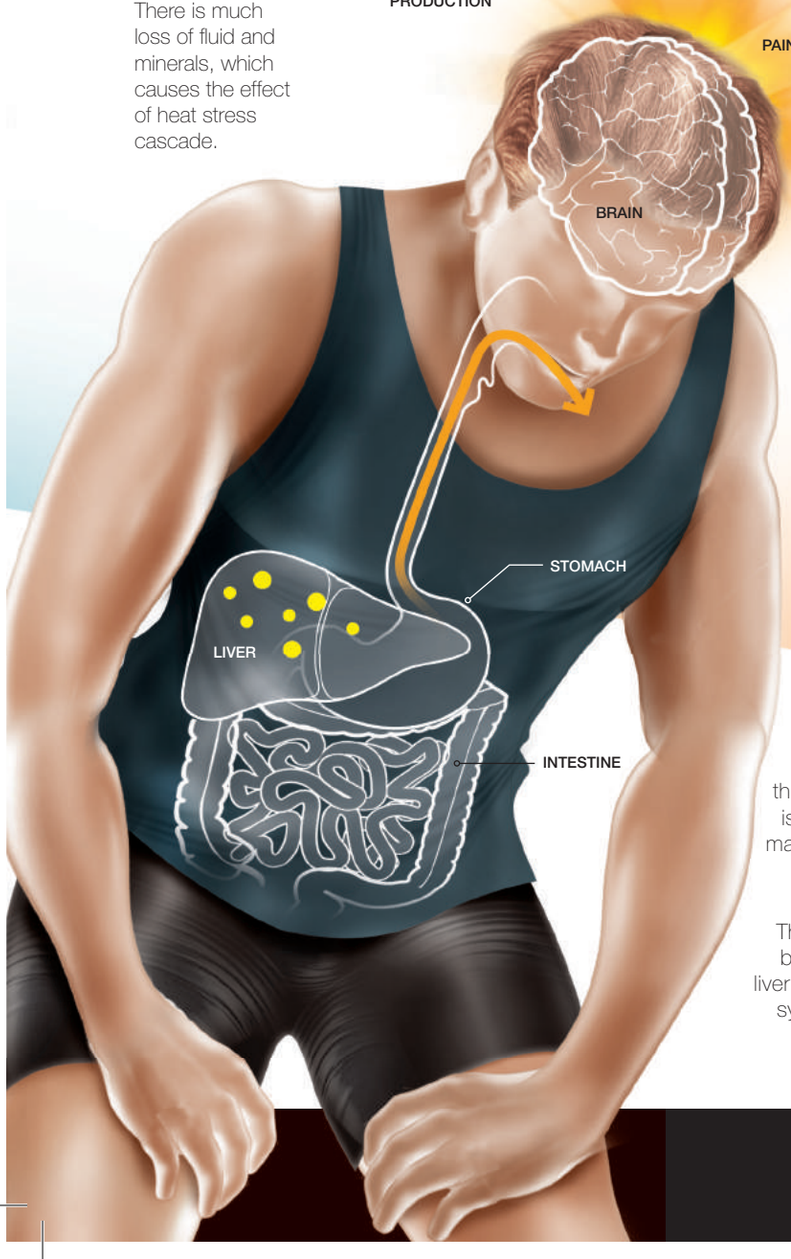
MOISTURE FACTOR

If it is high, sweat does not dry, core temperature does not decrease, and the nervous system activates the sweat glands even further. There is much loss of fluid and minerals, which causes the effect of heat stress cascade.



HEADACHE

Lancinating, it signals dehydration. Neurons cannot cope with the lack of water lost through sweat. Next, the athlete has mental confusion and often loses consciousness. There may be convulsions and death.



2%

DECREASE IN BODY FLUIDS ARE SUFFICIENT TO DECREASE CONCENTRATION AND AFFECT DECISION-MAKING, AND OTHER BRAIN FUNCTIONS

UPSET STOMACH

Blood ceases to circulate right through the digestive tract. There is nausea, the body's attempt to make the athlete stop at all costs.

IN THE LIVER

The fluid loss in the cells and the breakdown of proteins make the liver release toxins that the immune system understands as bacteria. The body goes into shock.

THE ATHLETE'S BODY TEMPERATURE

ABOVE 40 DEGREES CELSIUS
Heat stroke: there is a very strong threat to life.

40 °C
Nothing can be done except leaving the competition immediately. It is not possible to insist, due to total lack of physical conditions.

BETWEEN 38°C AND 40°C
when the sportsperson's body reaches this range, it is already showing signs of heat illness such as headache, nausea and contractions.

BETWEEN 37°C AND 38°C
in competitions of increased resistance and duration as the marathon, it is even expected that the core temperature should reach such range and stabilize in it.

37° C
it is the normal internal temperature of the human being.

HEAT AND SPORTS: A TROUBLED RELATIONSHIP

On 23 September 2015, a Brazilian women's football championship match in Teresina, Piauí, went down in national sports history. The match between Tiradentes (Piauí) and Viana (Maranhão) ended with a score of 10-0 to the home team, not for their technical superiority, but due to one external factor: the climate. The extreme heat in the Piauí capital at 3PM resulted in nine players from the Maranhão team falling ill on the pitch, diagnosed with dehydration and fatigue. Five had to be taken to the hospital. The match was suspended 36 minutes into the second half for lack of players. All players subsequently recovered.

The cyclist Marlus de Souza Freitas from Mato Grosso do Sul was not so lucky. On 18 October 2015, he suffered the ill effects seven hours after having completed a 102 kilometre competition in Rochedinho, district of Campo Grande, disputed in temperatures of 40°C. Freitas died of severe dehydration in Santa Casa Hospital, Campo Grande.

Both cases occurred in one of the hottest periods of Brazil's history, in the hottest year on record since global thermometer-based records began in the 19th century. In September and October 2015, various Brazilian cities broke historic temperature records, due to the combined action of a strong El Niño and an underlying trend of planetary warming as a result of greenhouse gases. And these cases are indicative of what may be in store for sports - and for all other activities - in the coming decades, in an increasingly hotter Brazil.

Ambient temperature and relative humidity are linked to man's capacity to regulate body temperature and oxygen intake. During exercise, the human body is always working to maintain homeostasis, that is, the physiological balance of vital functions. However, in some adverse conditions, there is a tendency to lose this balance. The human body works within a very narrow temperature range, between 36.5°C and 38°C. As our core body temperature fluctuates little, exposure to heat or cold means that our body must apply mechanisms to generate or maintain heat in low temperatures and dissipate heat in high temperatures.

Our core body temperature increases to 38.5°C at 75% effort during exercise. This value does not increase any further because of thermoregulation mechanisms. Without them, the core temperature of the body would increase 1°C every minute of intense exercise. Excessive heat poses harm to the body in two ways: facilitating dehydration in low relative humidity conditions and prevent-

Player from Viana football team collapses in the pitch under the heat of Teresina

Wilson Filho/Cidade Verde

ing the body from dissipating heat in high relative humidity conditions. In both cases, if this limit is exceeded the body enters into shock, unable to regulate internal temperature, so-called "exertional heatstroke" and the victim may die.

Increasing high temperatures have demanded and will continue to demand an even greater effort by the sports sector to adapt. This activity moved R$ 67 billion 2012 (1.6% of Brazil's GDP) and is in the public eye´s the country in 2016 due to the Olympic Games in Rio.

The Olympic Games have already reacted to this need to adapt. The kick-off for the six football matches that will take place in the Amazonia Arena, in Manaus, for example, have been changed. The Organizing Committee for the Olympic Football Tournament in Manaus opted to push back the times of the games that were programmed to take place in the early afternoon. Now all will take place after 6PM, due to the extreme heat in the Amazonas capital during the event. "We asked for this change as the first match of the day was planned for 1PM. This would be very hot, both for the players and the spectators. It would not have been appropriate and therefore we chose the adapted timetable as a public health consideration", said Mario Aufiero, state coordinator for the Manaus Committee 2016.

The Brazilian national team coach, Tite is also a fan of holding matches at times which do not compromise the performance and physical integrity of the athletes. Recently, as the coach for Corinthians during the 2016 Brazilian Championship, he publicly complained to the CBF (Brazilian Football Confederation) for having planned a match

between Corinthians and Botafogo at 11AM. “For athletes who have to work, this time is inhumane. And it won’t do to criticise me, as I know what I am talking about. Playing at 11AM is inhumane”, he said. Tite created such a fuss that the match kick off was moved to 4PM.

Player William Thuram, who played for the Campeonato Paulista da Série A-2 (São Paulo championship for second division teams in the state) for Mirassol in 2016, chimed in with Tite. “Playing in elevated temperatures is not only complicated in the North-East of Brazil. I played at the same time, 11AM, in São Paulo during the summer and it is complicated. Your body is put under extreme stress. And playing at 11AM changes the whole preparation routine. The player doesn’t sleep well, he doesn’t eat properly in the morning and then he has to subject himself to a superhuman effort in very high temperatures”, he said.

Players have also felt the impact of working in high temperatures. In the Rio championship in 2010, the attacker Fred, from Fluminense, used the same word as Tite - “inhumane” - to complain about a match played at 4pm (summer time) against Bangu in Maracanã, at 39ºC.

In the same year, footballers from Rio Grande do Sul took their complaint much further than the post-match press conferences. The Sindicato dos Atletas Profissionais do Estado (State Professional Athletes Union) went to the Labour Courts to request a ban on matches between 10AM and 6PM. Athletes won in the original hearing, but the FGF (Federação Gaúcha de Futebol: Football Federation for the state of

Cyclist Marlus Freitas, who died in 2015

Rio Grande do Sul) appealed the decision, as they feared that they would no longer receive the same amount from TV channels for buying match broadcasting rights.

During the Olympics in Rio, a number of professional athletes foresee difficulties in some sports. Those who are not acclimatized to the heat typical of the Rio de Janeiro winter may miss out on a chance to win a medal. Fernando Meligeni, second best male tennis player in the history of the sport in Brazil, believes that European tennis players will find it difficult to play during the Rio Olympics. “The problem for them is not so much the temperature, but the humidity. Tennis players are used to high temperatures and even sudden changes in temperature, moving from one continent to another. The problem with Rio will be the humidity. This makes the

player sweat a lot, lose liquid. It is easier to play in a dry climate. I believe that the English and the Swedish, for example, will fade out", he said.

Trying to improve the situation for tennis players, the Professional Tennis Players Association imposed a requirement that defends the physical integrity of the competitors: no match can be started at an ambient temperature above 34°C. At the end of the Brazil Open in 2001, in Salvador (Bahía), Meligeni suffered with the high temperatures. He lost a lot of fluid and as a consequence suffered severe cramps, which led him to lose the match.

Robson Caetano, Brazil's most successful sprinter and holder of the South American 100-metre sprint record since 1988, with a time of 10 seconds, confirms that both excessive heat and cold are an athlete's enemies. "Extreme heat leads to burnout. Cold leads to muscle contractions. Both are terrible. However, athletics has tried to adapt. Competitions only take place between 9AM and 12PM at which point they stop. They start up again at 5PM and continue until 10PM. This protects the physical integrity of athletes."

A mountain biker Raiza Goulão, who is going to represent Brazil in the Olympics, hopes that the temperatures are amenable in Rio. "There is a rule in Mountain Bike. The competitions are cut short when the heat is very intense." The athlete reveals some measures taken by athletes in this sport to flee the heat. "If the heat is very intense I reduce my warm-up and I add a pre-competition ice jacket and sun shade to keep my body cool up until the start time." She also believes that European athletes will have trouble in her sport.

WHAT SPECIALISTS SAID

William Thuram
(football player)
"I played in São Paulo, during the summer, at 11am. It's complicated. Your body is put under extreme stress."

Tite
(Brazilian national team coach)
"Games at 11am are good for supporters, who are at home getting the barbeque ready. But for athletes, who have to work, that time is inhumane."

Robson Caetano
(retired sprinter)
"Human beings are a virus attacking a living thing that is the planet. We are trying to adapt to adverse conditions that we ourselves are creating. We are all suffering from this and sport is no exception."

Raiza Goulão
(mountain biker)
"I think that the heat will obviously have an impact on the Olympics, as we saw in the test event. Europeans are not so used to these temperatures, but large delegations have been working at acclimatization for some time now."

ADAPTATION IS POSSIBLE, BUT IT IS EXPENSIVE

The Qatar World Cup, in 2022, will be the first in the history of the competition to be held during the months of November and December. Traditionally played throughout the months of June and July in Europe, the Americas and the East, the first World Cup in the Middle East was pushed back to the end of the year because of the heat - in June and July the maximum temperatures in Doha easily hit 40ºC. If it were played in the middle of the year, the temperatures would be prohibitive for the athletes. Changing the dates to the end of the year, the cup will be played during the end of autumn and beginning of winter. The new FIFA president, Gianni Infantino, has already officially announced that the end of the World Cup 2022 will fall on the 18 December, one week before Christmas.

Even so, the organizers are building air-conditioned stadiums for the competition. “Our plans did not change. The stadiums will not be used solely for the World Cup, we also have a national championship which we will use them for, even though we play between September and May, when it is cooler. Air conditioning will be installed in the stadiums in any event, and may open up new horizons for other countries, as the technology is also applicable to open and public spaces. Other countries that cannot organize events of this type due to the climate will be able to work with us to find a solution”, stated Nasser AL Khoter, president of the World Cup 2022 Organizing Committee. The technology, of course, comes at a price: the Cup in the desert is expected to cost Qatar US$ 30 billion,

Fernando Maia/Agência O Globo

or approximately R$ 100 billion. To compare, the 2014 World Cup cost Brazil R$ 27 billion.

Qatar is taking the hosting of the Cup in a hot country so seriously that it sent doctors to Brazil in 2014 to study athletes' performance on the hottest days of the competition. Two matches (Switzerland and Honduras in Manaus and Holland and Mexico in Fortaleza) were played in conditions with an extreme risk of heatstroke, which made FIFA impose technical breaks of 3 to 4 minutes after 30 minutes of play for players' rest and rehydration. A study by Qatari doctors published in the *British Medical Journal* indicated that, in matches during which the temperature came near to these extreme conditions, players were slower in their sprints and covered less distance in each run. However, the efficiency of their passes improved, which researchers attributed to an unconscious effort by the professional players' bodies to adapt.

The textile industry has also contributed with the so-called smart fabrics, used to either maintain athletes' bodies warm in low temperatures or to cool their bodies in higher temperatures. In the tennis, since the 2014 Australian Open, when temperatures soared to 40ºC, only games programmed at the Rod Laver Arena and the Hisense Arena went ahead, as they have retractable roofs. The others, on open air courts, were postponed for later dates.

Fluminense center-foward Fred cools himself duting match against Bangu in 2010

WHAT SPECIALISTS SAID

Flavio Saretta
(retired tennis player)
"Playing in Rio takes it out of you. High temperatures, humidity. You must be very well prepared, hydrated and highly focused. If not, the climate will destroy you."

Turibio Leite de Barros
(physiologist)
"The games at 11am are a success with the spectators and may even be more convenient for a Sunday given the timing. However, the 'artists' responsible for the show are exposed to risks that must be avoided."

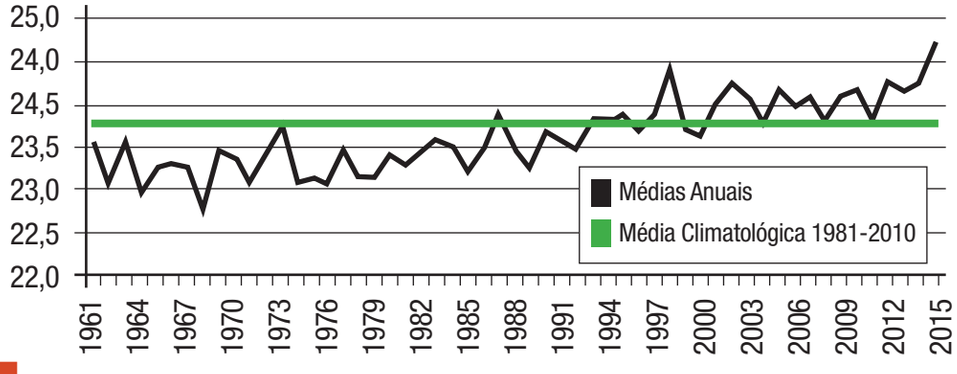
BRAZIL'S NEW CLIMATE

Brazil is already suffering the impacts of global warming. However, understanding the real extent of it is not so simple. Firstly, because the data available in this area are either very sparse, very recent, or both. Also, South America is heavily influenced by the natural, long-term warming and cooling cycles of the Atlantic and Pacific oceans.[1] The "noise" of natural variability is so high that it makes it difficult to distinguish climate change's "signal" caused by greenhouse gases.

Another complicating factor is that weather stations located in Brazilian cities suffer from the urban heat island effect. Even with these uncertainties, it is possible to confirm that Brazil has warmed more than the global average. While the world warmed 1°C last century,[2] Brazil warmed 1°C between the years 1961 and 2015 alone, according to the average of 237 weather stations maintained by the National Meteorological Institute (INMET) across the country.[3] In some places the thermometer rose considerably more than this.[4]

A significant part of this warming started to take place at the beginning of the 21st Century, when temperatures rose above the recor-ded average for the period 1981-2010. Here, Brazil is in line with the world trend: since global thermometer-based records began in 1880, 15 of the 16 hottest years have occurred since the year 2000. The 12 warmest winters in the last 50 years of the country's history occurred between 1998 and 2015, with variations in temperature of more than 3°C above the average in some regions, according to INMET. The increase in average temperatures, however, is only one of the possible means to measure warming. In order to understand the real impact of climate change on society, we must turn to the extremes. These are increasing throughout Brazil.

ANNUAL AVERAGE TEMPERATURES IN BRAZIL FROM 1961 TO 2015



Source: INMET

Average temperatures in Brazil on degrees Celsius, as measured in 237 meteorological stations kept by INMET

Climatologists use several different indicators to measure changes in climate. It is possible, for example, to measure the average maximum temperatures of a specific year, or the average minimum temperatures. Or the number of hot nights. Or the number of consecutive days with temperatures above 25°C. Or the number of consecutive dry or humid days.

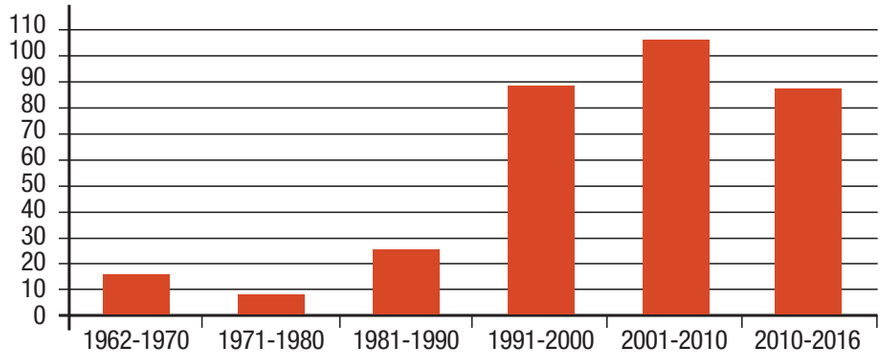
A number of Brazilian cities have experienced peaks of maximum temperatures in recent years. This was particularly marked in 2015 – thus far the hottest year in recorded history. That year, according to data compiled by the meteorologist Francisco de Assis Diniz, from INMET, the following set new peak temperature records: Manaus (39°C), Goiânia (39.9°C), Belo Horizonte (37.7°C) and Brasília (36.4°C). The town of Unaí in Minas Gerais reached temperatures of 42.5°C in October that year. Cuiabá broke another type of record - that of the greatest number of days with a maximum temperature equal to or greater than 40°C with a total of 15 days in the month of September alone. In some cases, particularly in the central region of Brazil, the increase in temperature is accompanied by an increased number of days with low relative humidity.

The trend in recent decades is for a lower relative humidity in cities such as Brasília and Presidente Prudente (São Paulo).

Another factor that has attracted climatologists' attention is that there is a consistent trend towards increasing temperatures across the country. In Brasília, this increase represents 2°C since 1961,[5] with an increased number of hot nights (the number of nights per decade with a temperature above 20°C doubled in the capital between 1962/1970 and 2000/2010) and an increase in the number of the so-called "summer days", with maximum temperatures over 25°C. But those with real trouble sleeping are the people from Tocantins state: the central region of the state suffered no less than a 5.6°C increase in the average annual minimum temperatures during this period, according to a report from the Brazilian Panel on Climate Change.[6]

Generally, the number of consecutive hot days increased and of consecutive humid days fell across most of the country. The exception is in the South, where the climate has been more variable and precipitation has increased.

WARM NIGHTS IN BRASÍLIA



Number of nights per decade with temperatures above 20ºC since the beginning of record keeping in the city; the trend is also verified in other regions

Source: INMET

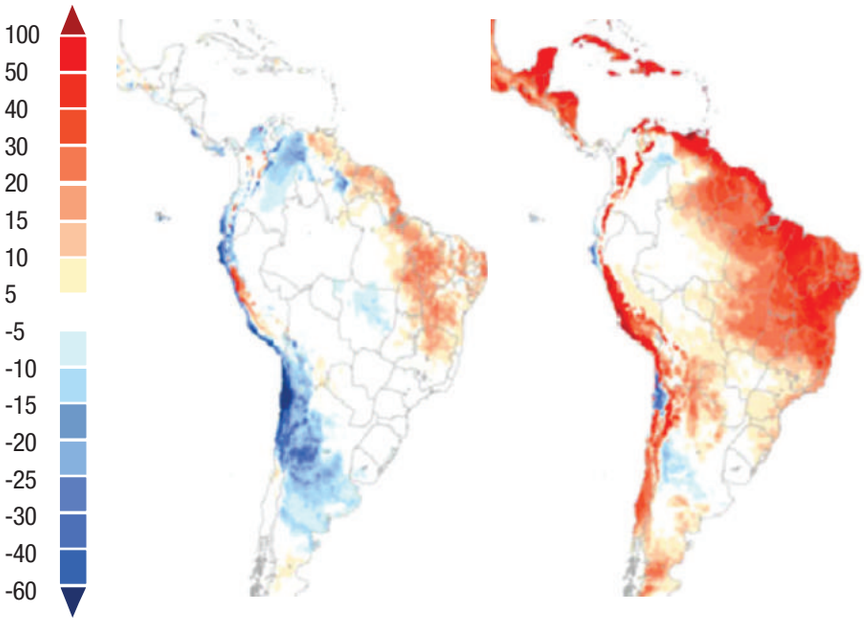
LIMITS TO ADAPTATION

These extremes in temperature and humidity directly impact the human body, which, as you saw in the previous chapters, functions best within a very narrow temperature range. Throughout recent decades, scientists have created indices to measure the body's resistance to elevated temperatures based on what is known about human physiology. Being aware of these indices is important for workers' health. Employers, for example, must know how much outside work their employees can handle in very hot places before risking suffering heatstroke. The same applies to athletes.

There are two main indicators used today in occupational health: WBGT (wet-bulb globe temperature) and UTCI (universal thermal climate index).

WBGT, the most common, consists of a combination of parameters - primarily temperature and humidity - to determine what the exposure time limit per hour for workers is if they are to maintain their body temperature at a maximum of 38ºC and avoid damage to the body. In situations of high temperature and high relative humidity, the body can no longer dissipate heat through sweat. Heart rate increases to maintain transpiration, temperature increases and the person enters into shock.

WBGT is different to maximum temperature: for the same air temperature, the index will be greater in Manaus (Amazonas) than in Cuiabá (MatoGrosso), given the high humidity of the Amazonian capital. In São Paulo, for example, a maximum temperature of 30ºC corresponds to a WBGT of 25ºC.

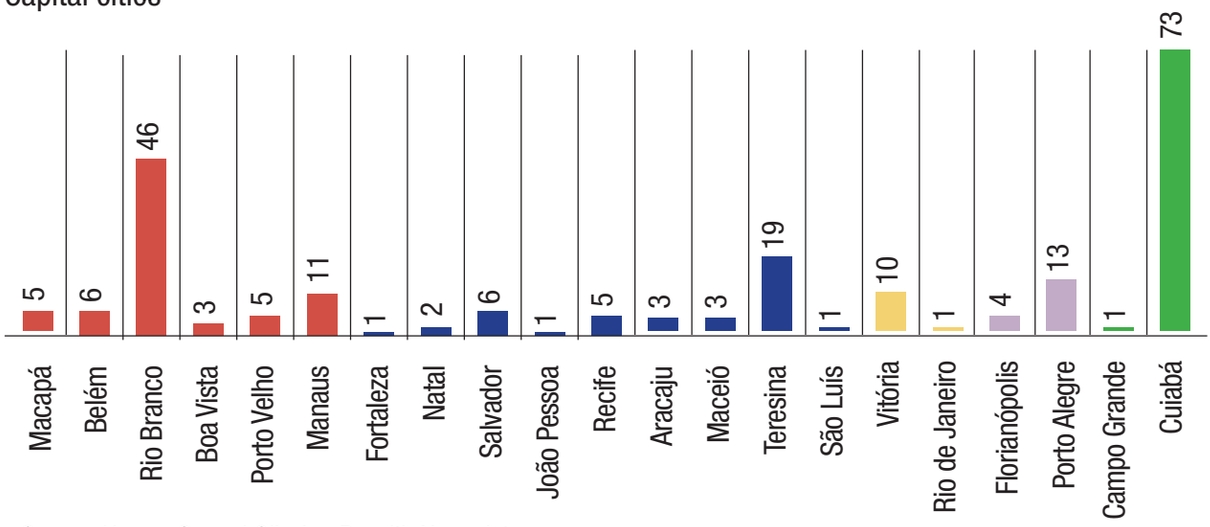


CONSECUTIVE DRY DAYS

The maps show Inpe's regionalized global climate model projections of the number of consecutive dry days in Brazil in 2071-2099 compared to the present (1961-1990). The map on the right shows the high-emissions scenario.

NUMBER OF DAYS WITH WGBT > 31ºC (1980-2015)

Capital cities



Source: Hacon, S., and Oliveira, B., with Noaa data

In the literature, a WBGT below 28.6ºC is considered a situation of thermal comfort, in which an acclimatized worker undertaking moderate physical exertion does not need to take a break from his/her activities. At 30.6ºC it is only possible to work risk-free for half an hour of every hour. Wet-bulb temperatures above 35ºC are considered to be the limit for the human body: to live in such a climate it would be necessary to have access to air conditioning 24 hours a day. Beatriz Oliveira, a post-doc at the Fiocruz National School of Public Health, in Rio de Janeiro, explains that no place on earth has exceeded the wet-bulb temperatures of 35ºC for long periods. But some places, Brazil among them, have come close. Between 1980 and 2015, six Brazilian capitals experienced ten days or more with WBGT above 31ºC. The record holder is Cuiabá, with 73 days, followed by Rio Branco, with 46 days, according to data compiled by Oliveira and Sandra Hacon, her surpervisor at Fiocruz.[7]

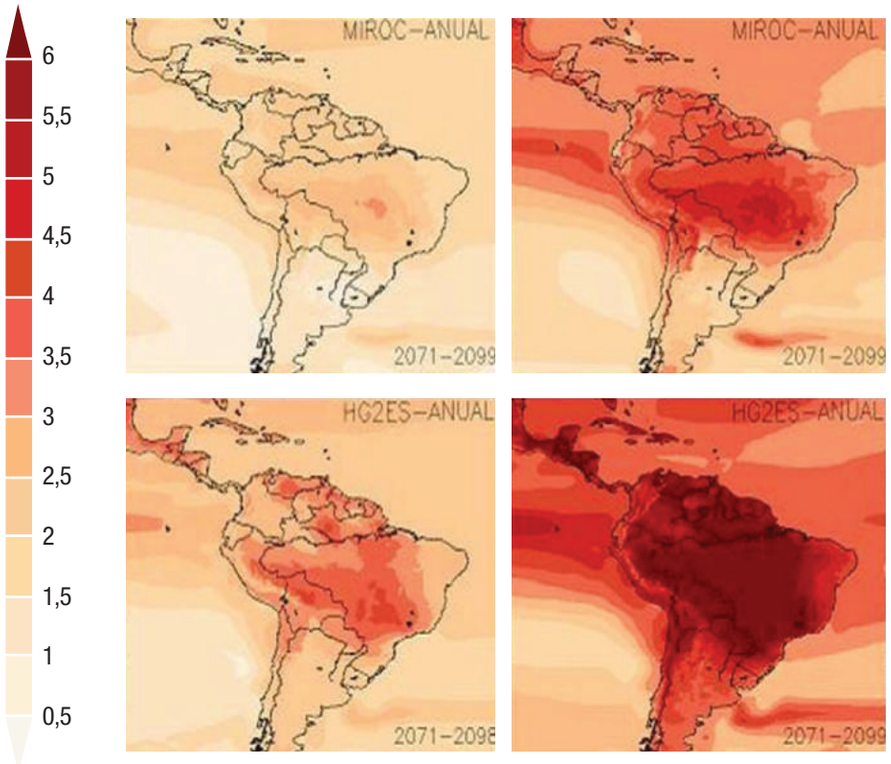
Physiological limits also vary from person to person, confirms Oliveira. Depending on factors such as acclimatization, living conditions and physical activity, this limit might be higher or lower.

The WBGT index is also taken seriously in sports. FIFA has a rule according to which football matches must be interrupted (for so-called “cooling breaks”) when the WBGT reaches 32ºC. In the 2014 World Cup, this threshold was exceeded in two matches. An analysis of athletes’ performance in the Cup showed that the higher the temperature, the lower the number of sprints and distance covered by players in a run.[8] This report uses FIFA criteria to define “risk to sporting practice” as being a threshold of 32ºC for wet-bulb temperature.

WHAT THE FUTURE HOLDS

If the current climate is cause for concern, Brazil's situation in the coming decades could be even more alarming. Making forecasts for temperature, rain, humidity and other parameter variations, however, is equally challenging - especially at the subcontinental level, such as the country or regional level.

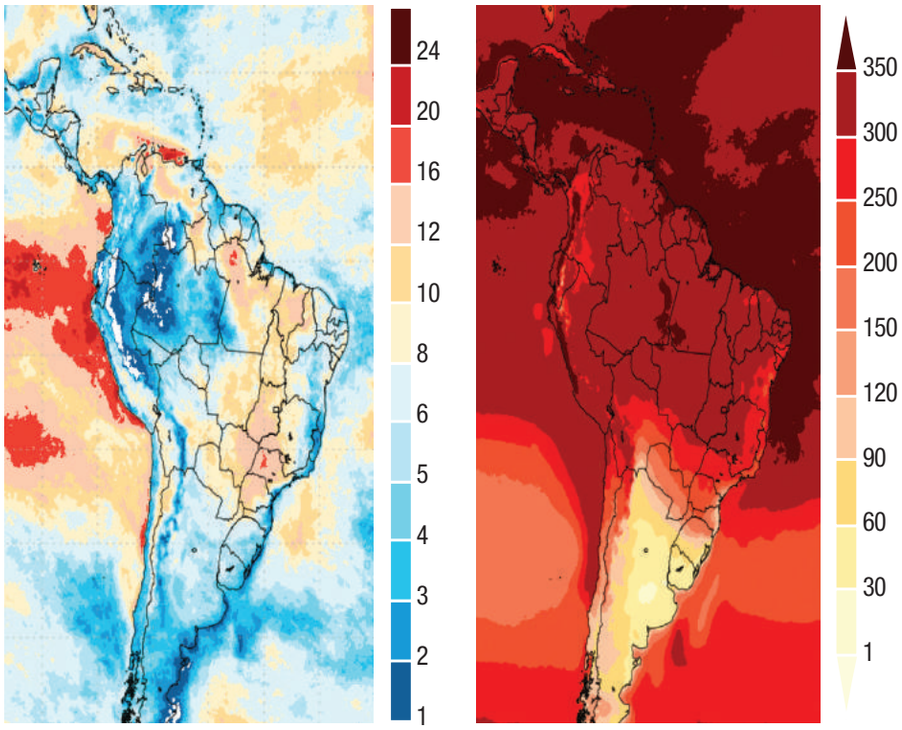
The IPCC (Intergovernmental Panel on Climate Change), a committee of scientists selected by the UN to assess the state of human knowledge on the matter, published a series of results from global climate simulation models in 2013 that show a much warmer world at the end of this century if drastic action is not taken to cut greenhouse gas emissions. These models indicate various degrees of global warming in accordance with the trajectory of global emissions. In the best-case scenario, the so-called RCP 2.6 (which takes this name because the additional energy contributed by man to the climate system in this pathway is equivalent to 2.6 Watts per metre squared), the temperature in 2100 will increase around 1°C (between 0.3°C and 1.7°C) in relation to the period 1986-2005;[9] in the worst-case scenario, the so-called RCP 8.5 (in which the contribution of humanity to planetary energy imbalance reaches 8.5 Watts per metre squared), the temperature would rise by

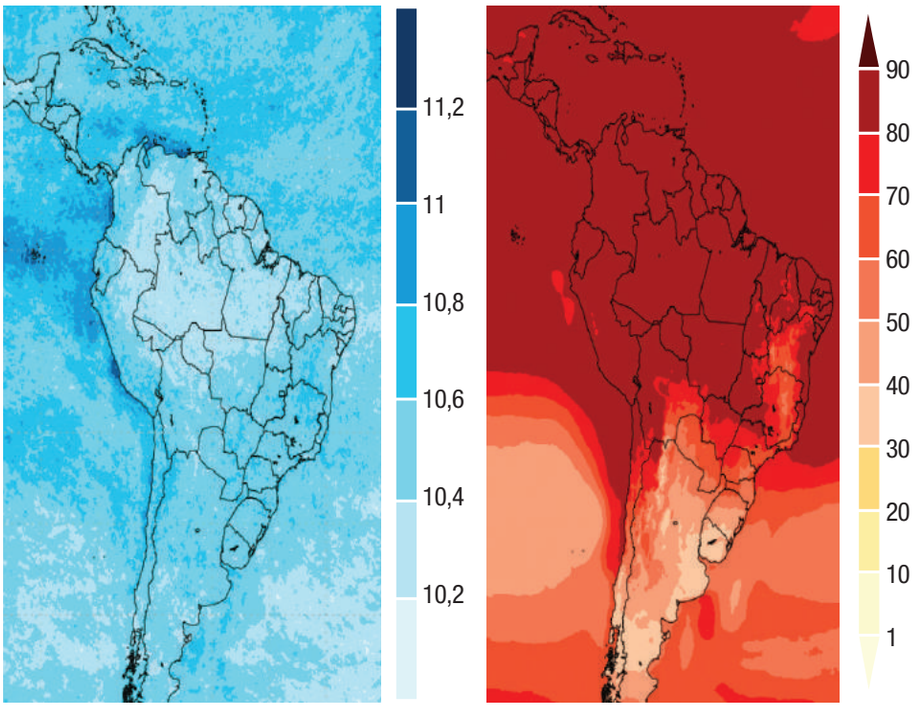


ANNUAL AVERAGE TEMPERATURES
The maps show the temperature difference in degrees Celsius between the end of the century and present time in Brazil according to Inpe's regionalized projections of two global climate models: Miroc-5 and HadGEM2. The maps in the second row consider a high-emissions scenario

WARM SPELL DURATION

The map on the left shows the number of days in the year in which temperatures remained for six consecutive days among the highest values of the 1961-1990 average. The map on the right shows the projection for this same parameter for 2071-2099 in a high-emissions scenario, according to Inpe's regionalized version of the HadGEM2 global model





WARM NIGHTS

The map on the left shows the percentage of nights in the year with higher temperatures according to the 1961-1990 average. The map on the right shows how mig that percentage would be in 2071-2099 in a high-emissions scenario, according to Inpe's regionalized version of the HadGEM2 global model

Source: Chou, S. C. et al., Assessment of Climate Change over South America under RCP 4.5 and 8.5 scenarios. American Journal of Climate Change, dec. 20145

Impacts: tomorrow

3.7ºC (between 2.6ºC and 4.8ºC). Currently, even by rigorously complying with the targets proposed by countries in the Paris Agreement, the world would still warm up by nearly 3.1ºC in relation to the pre-industrial era.[10]

The models used by the IPCC, however, apply a 200 km by 200 km scale. This is a low resolution to apply to regional forecasts, as some climatological processes that affect a region, such as storm systems, occur on a small scale. In Brazil, this gap is being closed by a National Institute for Space Research (INPE) group, led by Sin Chan Chou. They created regionalized versions, with 20 km by 20 km cells, of two climatic models: the British HadGEM2, which tends to envision a warmer and drier world, and the Japanese MIROC5, which tends to envision a cooler and wetter world. These computational models were run to try to understand what will happen with the climate of South America and Brazil in the years 2040, 2070 and 2100, following two possible hypotheses of CO_2 emissions: the RCP 8.5 scenario and an intermediate scenario of RCP 4.5.

In all scenarios, the Mid-West and parts of the South-East and the North of Brazil suffer sub-

Gabriel de Paiva/Agência O Globo

Street thermometer during heatwave in Rio de Janeiro in 2003

1º

Was the total warming measured in Brazil between 1961 ans 2015, considering average temperatures verified in 237 stations kept by the National Meteorology Institute all over the country

15 years

out of the 16 hottest years ever measured since records began in 1880 occurred in the 21st century. The only exception is 1998, when a very strong El Niño pushed thermometres up all over the world

stantial warming by the end of the century. In 2100, in the worst-case scenario from the HadGEM2 model, parts of Amazonia rise 9ºC in comparison to now. In 2040, the MIROC5 model forecasts a 2ºC warming in relation to current summer temperatures, while the HadGEM2 forecasts up to a 4ºC increase.

The maps on the previous page show simulations of the annual average temperature in Brazil for the RCP 4.5 model (left column) and the RCP 8.5 model, according to MIROC5 forecasts (top line) and from HadGEM2.[11]

The INPE group also calculated other climate extreme parameters, such as the number of hot nights, in which nocturnal temperatures remain in the 90th percentile, that is, the highest 10%, and the number of consecutive hot days. In the worst-case emissions scenario in the HadGEM2 model, most of the country would have hot days occurring practically all year round. Brazil would permanently be subject to elevated thermal stress, incurring risks to the health of the population - particularly the elderly and children, who have more difficulties with acclimatization. In some regions of Amazonia, it would be impossible to live without access to air conditioning.

9º

Is the maximum warming forecast in parts of Amazonia by the end of the century in high-emission scenarios simulated by INPE's regionalized climate models

73 days

Was the number of times the city of Cuiabá experienced wet-bulb globe temperatures above 31ºC (strong heat stress) since 1980; wet-bulb temperatures consider heat and air humidity

RISKS TO SPORTS

In Brazil there is still no overall map for wet-bulb temperatures which takes into consideration the regional forecast made by INPE. An initial effort was made by Hacon and Oliveira[12] using data from the Climate Chip, Ruby Coast Research Centre project, in Mapua, New Zealand.[13] The New Zealand group, led by Swedish researcher Tord Kjellstrom, created a system which allows for maximum temperatures, WBGT and UTCI to be monitored in all areas around the world using data from five global models used by the IPCC (including HadGEM and MIROC). Despite its low resolution, significant conclusions can be derived from the data compiled by the Fiocruz researchers.

Considering the worst-case emissions scenario (RCP 8.5), 98% of Brazilian municipalities would experience an average temperature increase in excess of 4ºC by the end of the century. At least 267 municipalities would exceed the WBGT of 35ºC in the hottest month of the year. These municipalities are in the North and Mid-West of the country. In total, 9.5 million people would be exposed to these conditions, with an expected increase in the number of admissions to hospital and deaths as a result of cardiovascular and respiratory diseases, especially among two vulnerable groups - the elderly and children.

Using the data from Kjellstrom et al and the WBGT value considered by FIFA as harmful to athletes ("stop play"), it is also possible to

TIMES OF THE YEAR WHEN TEMPERATURES WOULD BE TOO HIGH FOR OUTDOORS EXERCISE, ACCORDING TO HIGH-EMISSIONS SCENARIO FOR THE END OF THE CENTURY

SÃO PAULO
Time of the year: none
Annual heat stress: moderate
Average temperature: 20.8ºC
Average temperature, 2090: 24.7ºC
Difference: 3.9ºC

RIO DE JANEIRO
Time of the year: none
Annual heat stress: strong
Average temperature: 24.1ºC
Average temperature, 2090: 27.8ºC
Difference: 3.7ºC

CURITIBA
Time of the year: none
Annual heat stress: moderate
Average temperature: 18.6ºC
Average temperature, 2090: 22.4ºC
Difference: 3.8ºC

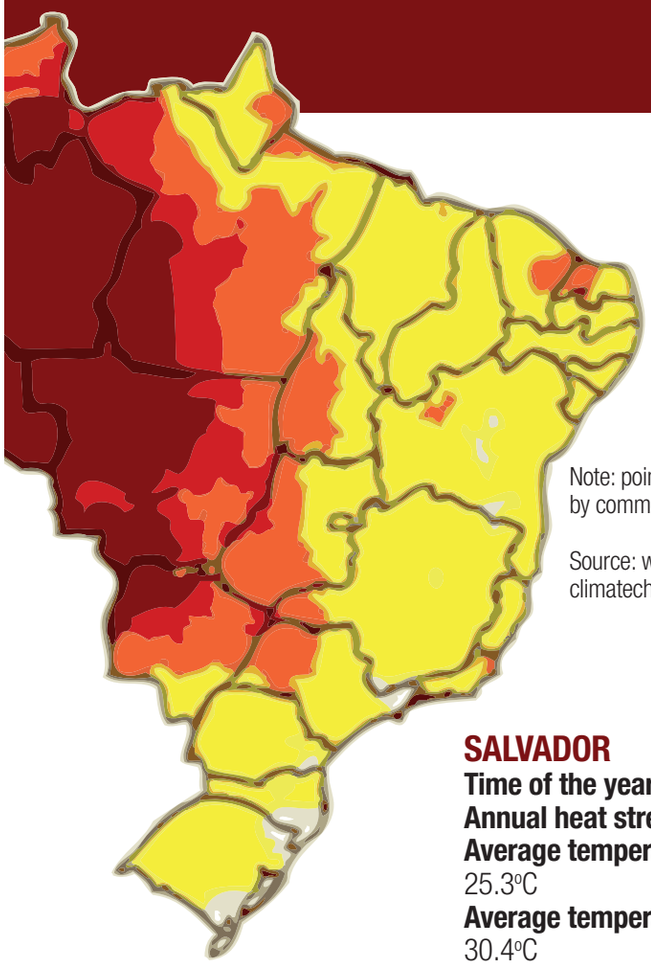
PORTO ALEGRE
Time of the year: none
Annual heat stress: moderado
Average temperature: 20.5ºC
Average temperature, 2090: 23.7ºC
Difference: 3.2ºC

CUIABÁ
Time of the year: Jan/May, Aug/Dec
Annual heat stress: very strong
Average temperature: 27.4ºC
Average temperature, 2090: 34ºC
Difference: 6.6ºC

BRASÍLIA
Time of the year: none
Annual heat stress: strong
Average temperature: 23ºC
Average temperature, 2090: 28.5ºC
Difference: 5.5ºC

GOIÂNIA
Time of the year: none
Annual heat stress: very strong
Average temperature: 24.9ºC
Average temperature, 2090: 30.5ºC
Difference: 5.6ºC

PALMAS
Time of the year: Feb/Apr, Oct/Nov
Annual heat stress: very strong
Average temperature: 27.7ºC
Average temperature, 2090: 33ºC
Difference: 5.3ºC



Note: points replaced by commas

Source: www.climatechip.org

MANAUS
Time of the year: Year-round
Annual heat stress: very strong
Average temperature: 28.2ºC
Average temperature, 2090: 34.4ºC
Difference: 6.2ºC

RIO BRANCO
Time of the year: Year-round, except July
Annual heat stress: very strong
Average temperature: 27ºC
Average temperature, 2090: 33.5ºC
Difference: 6.5ºC

FORTALEZA
Time of the year: none
Annual heat stress: strong
Average temperature: 27.2ºC
Average temperature, 2090: 30.8ºC
Difference: 3.6ºC

SALVADOR
Time of the year: Jan, Dec
Annual heat stress: strong
Average temperature: 25.3ºC
Average temperature, 2090: 30.4ºC
Difference: 5.1ºC

TERESINA
Time of the year: Oct/Nov
Annual heat stress: very strong
Average temperature: 28ºC
Average temperature, 2090: 32.8ºC
Difference: 4.8ºC

MACAPÁ
Time of the year: Aug, Oct/Dec
Annual heat stress: very strong
Average temperature: 27.6C
Average temperature, 2090: 31.9ºC
Difference: 4,3ºC

BOA VISTA
Time of the year: Sep/Nov
Annual heat stress: very strong
Average temperature: 27.6ºC
Average temperature, 2090: 33.3ºC
Difference: 5.7ºC

SÃO LUÍS
Time of the year: Oct/Dec
Annual heat stress: very strong
Average temperature: 27.9ºC
Average temperature, 2090: 32ºC
Difference: 4.1ºC

CAMPO GRANDE
Time of the year: Feb, Oct/Dec
Annual heat stress: very strong
Average temperature: 25ºC
Average temperature, 2090: 30.4ºC
Difference: 5.4ºC

FLORIANÓPOLIS
Time of the year: none
Annual heat stress: moderate
Average temperature: 19.6ºC
Average temperature, 2090: 22.8ºC
Difference: 3.2ºC

JOÃO PESSOA
Time of the year: none
Annual heat stress: strong
Average temperature: 26.3ºC
Average temperature, 2090: 29.7ºC
Difference: 3.4ºC

RECIFE
Time of the year: none
Annual heat stress: strong
Average temperature: 25.8ºC
Average temperature, 2090: 29.3ºC
Difference: 3.5ºC

NATAL
Time of the year: none
Annual heat stress: strong
Average temperature: 26.5ºC
Average temperature, 2090: 30ºC
Difference: 3.5ºC

ARACAJU
Time of the year: none
Annual heat stress: strong
Average temperature: 26ºC
Average temperature, 2090: 29.8ºC
Difference: 3.8ºC

VITÓRIA
Time of the year: none
Annual heat stress: strong
Average temperature: 25.2ºC
Average temperature, 2090: 28.8ºC
Diferença: 3.6ºC

BELO HORIZONTE
Time of the year: none
Annual heat stress: strong
Average temperature: 21.7ºC
Average temperature, 2090: 26.6ºC
Difference: 4.9ºC

BELÉM
Time of the year: Apr/Dec
Annual heat stress: very strong
Average temperature: 27.8ºC
Average temperature, 2090: 32ºC
Difference: 4.2C

PORTO VELHO
Time of the year: Year-round, except Mar/Jul
Annual heat stress: very strong
Average temperature: 26.8ºC
Average temperature, 2090: 33.3ºC
Difference: 6.5ºC

MACEIÓ
Time of the year: none
Annual heat stress: strong
Average temperature: 25.5ºC
Average temperature, 2090: 29ºC
Difference: 3.5ºC

estimate the risks to practising sport in the country at the end of the century.

A total of 12 Brazilian capital cities may have wet-bulb temperatures which exceed 32ºC throughout some months of the year, periods in which it would be risky to do physical exercise in environments without climate control. The most dramatic situation is that of Manaus: if nothing is done to contain greenhouse gas emissions, the capital of Amazonas may become a place in which sport is forbidden all year round. In Rio Branco, the month of July would be the only month in which the WBGT would be not equal to or above 32ºC. In Cuiabá, June and July.

Considering the UTCI index, all Brazilian capitals may suffer some degree of thermal stress throughout the whole year. This will be moderate in São Paulo, Curitiba, Florianópolis and Porto Alegre, severe in the South-East, North-East and in Brasília and very severe in the remaining capitals in the North and Mid-West. In the hottest months of the year, parts of the Mid-West and Amazonia would have extreme levels of thermal stress.

ENDNOTES

1 – Painel Brasileiro de Mudanças Climáticas – Primeiro Relatório de Avaliação

2 – Warming recorded in 2015 in relation to the average between 1850 and 1900, according to the World Meteorological Organization. See: http://library.wmo.int/pmb_ged/wmo_1167_en.pdf

3 – AssisDiniz, F., personal correspondence

4 – PBMC (Brazilian Panel on Climate Change), op. cit.

5 – Almeida, Morgana V., Índices de Monitoramento e Detecção de Mudanças Climáticas no Centro-Oeste do Brasil. Master's Dissertation - Universidade Federal de Campina Grande, December 2012

6 – PBMC, op. cit.

7 – Hacon, S., and Oliveira, B., personal correspondence

8 – Nassis, G. P., et al., The association of environmental heat stress and performance: analysis of the 2014 FIFA World Cup in Brazil. British Medical Journal Sports Med, 2015, 49: 609-613

9 – IPCC, Climate Change 2013 – The Physical Science Basis. Summary for Policymakers. Available at http://www.climatechange2013.org/

10 – Rogelj, J., et al., Paris Agreement proposals need a boost to keep warming well below 2oC. Nature, vol. 534, 30 de junho de 2016

11 – Secretaria de Assuntos Estratégicos da Presidência da República, Brasil 2040 – Resumo Executivo.

12 – Nobre, C., Marengo, J., Soares, W., Assad, E., Schaeffer, R., Scarano, F., e Hacon, S., Riscos de Mudanças Climáticas no Brasil e Limites à Adaptação. Sumário executivo. Embaixada Britânica, 2016. Availableathttps://www.gov.uk/government/uploads/system/uploads/attachment_data/file/504489/Clima-Sumario-v3.pdf

13 – www.climatechip.org

Observatório
do **Clima**

Observatório
do **Clima**