It's Hot Outside!
by Sam Gutterman August 24, 2023

It feels like 116°F outdoors now (only 101°F without factoring in humidity) – but I'm indoors in comfortable air conditioning, sitting in front of my laptop. I am also thinking about those less fortunate than me, either working outside or who can't afford air conditioning. Compared with them, I'm doing OK, partly because this excessive heat is only here in Chicago for two days and my residential power supply is in good shape – at least this time. However, I realize that next year such a period is likely to be either hotter or longer.

I don't know what my reaction would be if I were living in even hotter conditions or if this heatwave lasted a month! But what are the primary impacts of this excessive heat?

First, let's discuss metrics. The number of degrees Celsius above pre-industrial levels on a global basis, that is, before modern economic conditions, is the most commonly referred to global metric. 1.5°C (2.7°F) is the aspirational target underpinning the 2015 Paris Agreement. But based on all reasonable estimates of greenhouse gas emissions, this will certainly be exceeded.

July 2023 shattered the monthly temperature record that goes back to at least 1850 by around 0.25°C. This seemingly small increase has produced heatwaves in many parts of the world. In many places, July was more than 8°C warmer than the average for the period 1951 to 1980. The average global temperature was 1.54°C above the preindustrial average for the month, already greater than the Paris aspirational goal. The total year could be the warmest on record, with next year likely being even hotter because of the expected-to-be even larger impact of the current El Niño condition. In addition, the long and brutal heat waves may not back down very much in the evening.

A more relevant metric is often what is referred to as a wet-bulb temperature, combining regular temperature and humidity. This is the 'feels like' temperature.

Although it is important to assess global averages, it is the local weather that can be more important (well, not always, because climatic factors don't respect local or even national borders). However, local conditions can experience even more volatility and extremes. Urban heat islands exacerbate the problem in many cities through an insufficient amount of green areas and too much concrete.

There are several underlying contributing causes to such an increase. In addition to a seemingly ever-increasing greenhouse gas concentration in the atmosphere, irregular volcanic eruptions and recurring climatic patterns such as the beginning of an El Niño warming event can play a part. Unfortunately, our increase in excessive heat is not a one-off occurrence and over the last few decades has been primarily due to greenhouse gas emissions and is not going away any time soon[1], with its volatility across time and space continuing. In addition, global ocean temperatures are also at an all-time recorded high.

Excessive heat can result in adverse outcomes in three ways: (1) directly, (2) together with other factors such as humidity or extreme levels of precipitation, or (3) starting a cascading set of conditions. The latter conditions include flooding, extra-intense storms, or infectious disease spread.

[1] The eight hottest years globally have just happened to have occurred over the past eight years.

Excessive heat can result in a wide range of adverse impacts, affecting human health, property, and our environment. As global temperatures continue to rise due to climate change, the frequency and intensity of heat waves are increasing[2], leading to more pronounced adverse effects, possibly of a non-linear nature after a tipping point is reached.

Alone, excessive heat can damage one's body through, for example, heat stress. However, simultaneous changes in other climatic factors, such as humidity, precipitation, and wind, can result in compound or cascading risks in the form of a threat multiplier. When accompanied by other climatic factors it can compound or cascade into another level or type of threats, both from the air or from bodies of water. For example, excessive heat along with dryness and wind can contribute to or cause the ignition of or rapid spread of wildfires; and along with excess precipitation, it can contribute to the spread of infectious disease.

Some of the key adverse effects of excessive heat, alone or in combination with other climatic factors include:

Heat-related illnesses and deaths. Heatwaves have been referred to as silent killers because they may not be the sole or direct contributors to death and since they aggravate existing health conditions. As a result, attribution can be difficult. However, with the heat waves sprouting up around the world in 2023, it has become increasingly recognized as a significant health risk. Exposure to excessive heat can result in symptoms like dehydration, fatigue, dizziness, nausea, confusion, heat stroke, and even loss of consciousness. In severe cases, these can be life-threatening. Heatwaves can significantly increase mortality rates, especially among vulnerable populations such as the elderly, children, and those with pre-existing health conditions or with limited resources. Over both the short and long term they can also exacerbate existing cardiovascular and respiratory conditions, leading to increased hospitalizations and fatalities, as well as affecting mental health.

Note however, that this discussion would be incomplete without noting that an increase in heat-related morbidity and mortality may also result in a reduction in cold-related morbidity and mortality.

Property damage. Although other aspects of climate change are more often thought of as major drivers of property damage, excessive heat can also affect physical resources. For example, thousands of houses in France are expected to be left with sizeable structural cracks after heatwaves, as they were built on clay soil that contracts during droughts. Almost half (48%) of land in France is now deemed at risk, including all along its Mediterranean coast. This year's heatwaves – and climate change in general – are exacerbating this problem. In addition, wildfires and storms, in part a result of excessive heat, can cause considerable damage to property of a wide-ranging nature.

The environment, including air and water. High temperatures can worsen air quality by promoting the formation of $PM_{2.5}$, ozone, and other air pollutants. These can exacerbate respiratory and cardiovascular problems and contribute to the development or exacerbation of conditions like asthma and bronchitis. This in turn can also impact the availability and quality of drinking water supplies, irrigation for

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[2] According to Emmanuele Russo and Daniela I.V. Domeisen (2023). "Increasing Intensity of Extreme Heatwaves: The Crucial Role of Metrics". *Geophysical Research Letters*, 13 July 2022. doi:10.1029/2023GL103540

agriculture, and ecosystems dependent on water sources. And this is in addition to ecosystem disruption and biodiversity loss.

Economic costs, including labor productivity. Heatwaves can result in significant economic costs due to increased energy consumption for cooling, reduced labor productivity, and damage to infrastructure (e.g., buckling roads and melting asphalt). They also reek of damage to agricultural output and food production, ranging from a lack of water, crop damage, and increased vulnerability to pests and disease. These can lead to food insecurity when food becomes unavailable or unaffordable. Overall, outdoor work can be affected. From a business perspective, inadequate action regarding mitigation, adaptation, or loss prevention can result in liability for contributing to all of the losses mentioned here.

The oceans. We often focus on the impact on the land. However, not only is the atmosphere getting warmer, but the oceans are as well. This can involve the mortality of sea creatures including fish and coral, contributing to the loss of livelihood of those involved in fishing. In addition, water acidification and more intense tropical storms can be caused by warmer oceans, resulting in ocean surges that contribute to flooding or ground subsidence, as well as over-salinization. Sea level rise can threaten coastal communities, especially those in low-lying areas and their infrastructure.

Adaptation. To reduce some of the adverse effects of excessive heat, it is crucial to implement strategies for adapting to and mitigating climate change. These strategies include reducing greenhouse gas emissions and carbon footprints, enhancing urban planning to include more green spaces and heat-resilient infrastructure, improving early warning systems for heatwaves, and promoting public awareness and preparedness for extreme heat events. Individuals can create their own heat action plans; for instance, runners finish their training runs before sunrise, and outdoor workers increasingly use cooling vests packed with ice or fans during extreme conditions. Air conditioners are turned on 24/7.

Through heat action plans, communities can help people keep cool, productive, healthy, and alive in periods of excessive heat. This is especially important for vulnerable individuals, for example, the elderly, the young, pregnant women, and the disabled. They may not have access to various adaptation techniques, such as air conditioning in their homes. Neighbors are encouraged to look in upon their vulnerable neighbors. By improving meteorological modeling, we may have available early warning systems that, along with effective communication of probable risks and outcomes, can prevent some of its adverse effects.

Open question. This discussion raises an unanswered question regarding to what extent are climate change factors contributing to mortality over the short or long term. I don't have a numerical answer, but I welcome discussion of probable scenarios and quantification of the morbidity and mortality costs, risks, and uncertainties.